JOURNAL

OF THE

Association of Engineering Societies.

St. Louis. Boston. St. Paul. Montana.
Pacific Coast. Detroit. Louisiana.
Utah.

CONTENTS AND INDEX.

VOLUME XLVI.

January to June, 1911.

PUBLISHED MONTHLY BY

Fred. Brooks, Secretary of the Board of Managers of the
Association of Engineering Societies.
31 Milk Street, Boston.

CONTENTS.

VOL. XLVI, January — June, 1911.

For alphabetical index, see page v.

No. 1. JANUARY.

No. 2. FEBRUARY.

No. 3. MARCH.

No. 4. APRIL.

No. 5. MAY.

No. 6. JUNE.

INDEX.

VOL. XLVI, January — June, 1911.

ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors are printed in *italics*.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVI. JANUARY, 1911. NO. 1.

WORK AT THE PANAMA CANAL.

BY LOUIS K. ROURKE, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[A talk before the Society, September 21, 1910.]

Mr. President and Gentlemen, — I wish to thank you for the honor of being permitted to meet such a distinguished body. When I accepted the invitation to speak here this evening, I hardly expected to see a member of the consulting board of engineers of the Panama Canal present to check me up. But I see he is here.

I haven't had the time or the inclination to prepare what you'd call a real engineering paper. My talk will be entirely informal, and what figures I shall give you will be approximate. If I come within one hundredth or one tenth of a foot on elevations, etc., you will kindly let that go. And during the talk if any of you wish to ask questions, do not hesitate to interrupt me.

This subject of the Panama Canal seems to me to be one in which every American should be interested. As to the necessity or desirability of the canal, that is a mooted question which is neither here nor there. The fact is, the canal is being built. In 1904, Uncle Sam, through his strenuous representative, Mr. Roosevelt, decided it should be built, and, this decision once reached, it appears to me to be the duty of every American to be interested in the work and to see that it is pushed through in the most economical and expeditious manner possible.

As a further incentive of interest on the part of the American people, I might call attention to the fact that the canal will cost every man, woman and child in the United States approximately $4 each, assuming the population to be approximately 90 000 000.

There is no need to burden you with the history of the various early attempts to construct a canal. You are all as familiar with them, no doubt, as I am. The last unsuccessful attempt was the De Lesseps attempt, which cost approximately $300 000 000. Now, the two principal reasons, to my mind, for the failure of these early attempts were lack of capital and lack of proper tools. The equipment had not been developed. The French had the best equipment of their day in the world, but it was not of sufficient size and strength to carry on such a stupendous work.

Now, I will give you a few figures which may be of interest. We paid the French company $40 000 000 for their rights and all their property, which included the Panama railroad. I think there were about 30 000 000 cu. yd. of useful excavation, so that we didn't secure a very bad trade on the whole, after we once decided to build the canal. In addition, we paid the Panama republic, so called, $10 000 000, for which we received some 120 000 acres of land and all the necessary rights for the construction and operation of the canal, besides several forms of political worries and cares too numerous to mention, which weren't in the bargain and which we still have with us.

From May 4, 1904, until January, 1907, we were engaged in preparatory work for the final construction of the canal, and at the same time trying to make the dirt fly to satisfy the just and the unjust critics — and there are a few just critics, you will admit; and, needless to say, to do work when you are not equipped to do it is a very expensive thing. That is what Mr. Stevens and Mr. Wallace were up against for two years. Until June, 1906, the type of the canal had not been decided. At that time Congress authorized the construction of an 85-ft. level lock canal.

The canal will be, from deep water to deep water, $50\frac{1}{2}$ miles long, with a channel approximately 45 ft. in depth. On the Atlantic side is a sea-level entrance about seven miles in length, with a channel 500 ft. wide, leading to the Gatun dam, three locks in flight, each of $28\frac{1}{3}$ ft. lift, raising the ships to the Gatun Lake, which is formed by an enormous dam across the valley of the Chagres at the foothills in Gatun on the Atlantic side, and a small dam and lock at Pedro Miguel on the Pacific side.

The dam at Gatun is an earth dam, with a slope about

1 vertical and 10 horizontal, and will contain about 22 000 000 cu. yd. of spoil when finished. The sailing distance through Gatun Lake is approximately 25 miles. The channel varies in width from 300 to 1 000 ft. At Pedro Miguel there is one lock which lowers boats to elevation 55. From there the vessels will run through a small lake called Mira Flores Lake, about a mile, to two locks, where they will be lowered to sea level and from there run in an 8-mile sea-level channel to the Pacific Ocean.

Investigation shows there is no question about the water supply being sufficient to operate a lock canal. The evaporation on the Isthmus is about 4 ft. a year and the rainfall about 10 ft. That is the average. On the Atlantic side they have as much as 12 ft. and on the Pacific side about 7 or 8 ft., but the average is about 10 ft. So much for the general outline of the canal.

The only engineering problem that struck me in connection with the canal was the control of the Chagres River, and when the lock canal was decided on, that solved the problem.

The canal follows the valley of the Chagres about 25 miles, when the Chagres River turns off to the northeast. The Gatun Lake at elevation 85 will back the water up the Chagres River about five miles above its entrance to the canal. The great trouble with the Chagres River is the enormous floods that occur there, it having been known to rise 40 ft. in 24 hr. Any sea-level advocates can imagine what would happen to a sea-level canal with that roaring torrent rushing in there. Under the present plan a flood in the Chagres River has about as much effect on the Gatun Lake as the Connecticut River, in flood, has on Long Island Sound.

So, to my mind, the problem was solved in the best possible way by the adoption of the lock canal, and it is hardly the time now to discuss the relative merits of the lock and the sea-level canal. That was done three years ago. The best canal that could be built is being built — considering navigation, maintenance and everything else.

The United States has been very fortunate, in my opinion, in the selection of the chief engineers of the Panama canal. The first incumbent of the office, Mr. Wallace, as far as I know, was responsible for the ordering and designing of the equipment that has been used there. And he should be given great credit for that, as the equipment has stood the test of five years' hard work, and outside of strengthening it a little, if we were going to start the canal to-morrow, we'd order practically the same equipment.

Mr. Stevens came next, and to him is due the credit of securing and organizing the vast army of men, about 40 000 in number, who are engaged in this work, and that was a big problem. To the present incumbent of the office, Colonel Goethals, is due the very great credit of taking this machine, turned over to him three and one-half years ago, keeping it running smoothly and doing the construction work expeditiously and economically. And to my mind, one of the great reasons for the success of these various men is that, to a very great extent, they were able to keep Washington off the job. In other words, politics were pretty fairly well eliminated.

Now, when you think of a tropical jungle like Panama, 2 000 miles from the base of supplies, New York; when you think of going into this jungle, where the French and other people that had been down there had died in large numbers on the work, providing houses and food for an army of 40 000 men, — with their families we have approximately 80 000, — you cannot but realize that it was a herculean task, apart from the engineering problems that might arise. The first and great thing was the sanitation of the Isthmus to eliminate the tropical diseases, which Colonel Gorgas has done. This will cost about $20 000 000, it is true, but I don't know how we could have dug the canal any other way. The chief problem, was to destroy the mosquito, the house fly and insects of all kinds that carry these tropical diseases. We have a sick rate there now about the same as in the city of Boston. It goes to show that the American, when he has the money and the will to spend it right, can do things.

The organization of the present engineering force is divided into three geographical divisions, each under a division engineer — the Atlantic division, extending from deep water on the Atlantic side to the Gatun dam and locks; the central division, extending from the Gatun dam to Pedro Miguel dam and lock, which is the great dry excavation division, 32 miles long, including the famous Culebra Cut; and the Pacific division, which extends from Pedro Miguel dam and lock to deep water on the Pacific side.

The work itself is divided into wet excavation, dry excavation and miscellaneous work of building the locks, dams and spillways. The wet excavation amounts altogether to about 75 000 000 cu. yd. and varies all the way from mud to hard rock. There are 16 dredges at work, 7 of which we inherited from the French — old Scotch dredges that the French used in their work. They are doing very fair, economical work. Two

large sea-going dredges, two dipper dredges and four large suction dredges are pumping into the Gatun dam.

All of these plants are self-sustaining. There are modern repair shops at the Pacific side to take care of the Pacific floating and land equipment.

The central division has the most modern steam-shovel repair shop, I presume, in the world. They employ about 600 men there, doing practically nothing but repairing and rebuilding steam shovels. The Atlantic division has large shops on the Atlantic side. And although on castings and many things we secure a little lower price in the States than it would cost us to make them there, still, when we are forced to do it, there is scarcely a piece of machinery on the Isthmus that can't be replaced there.

The spectacular part of the work on the Isthmus up to date has been the dry excavation, with which I was rather intimately connected. There are about 95 000 000 cu. yd. of excavation in the central division, about 80 000 000 of which was in the Culebra Cut, which is only nine miles long, but it is the backbone of the intercontinental range, and the canal passes through the lowest point. At the deepest point the cut will be 496 ft. deep, and the minimum channel through this cut is 300 ft. in width.

In March, a year ago, with 56 shovels, I think it was, I took out 2 065 000 cu. yd. of blasted material — it is all blasted now, the earth is all off — and hauled that an average haul of 12 miles to the dump at a cost of 49 and a fraction cents. I haven't seen any steam-shovel work any more efficient than that work of ours was down there, although the best we could get out of the shovels was about 67 per cent.; that is, there was 33 per cent. of the time, or a little less than one third, lost from waiting for cars, etc. We ran 190 trains a day, each of them averaging two trips a day, and to handle so many trains was a large transportation problem — why, the street cars in Washington Street are not any thicker than our dirt trains down there. Any little accident can tie them up. So the best we could do was to keep about 67 per cent. of our shovels at work. Steam-shovel men in the United States take care of their own shovels. That is part of their work. I thought it would be a pretty good investment to have the steam-shovel men digging dirt, while we took care of the shovels. I organized two elaborate floating repair crews. One started at one end of the cut and one at the other, after 5 P.M., while regular work in the cut had stopped. That increased our output pretty nearly 15 per cent. There-

after there were no repairs done by the steam shovel men except in emergencies.

In this dry excavation, the great problem is to drain the shovel pits. For that reason, the cut is run down on a slope from the summit, each way, north and south, and our dirt trains come in from the top, drop down into the cut and load up. The loads go down grade. Sometimes a train will stop at six different shovels before it has finished loading. We have had as many as five shovels working on one loading track. That is not an ideal proposition, but we have had fair success with it. Our steam shovels there are the ordinary 100-ton shovels, with 5 yd. dippers which can dig 12 ft. below the loading track.

Our system of excavation is to drill and shoot to about 14 ft., 50 ft. in width, before the pioneer cut goes through. A loading track is laid in the pioneer cut. The steam shovel next goes through loading on the loading track and digging 12 ft. deeper, which makes our cut 24 ft. The entire lift of the cut is then taken off, so there is a series of terraces and different levels working through all the time. We have as many as five different levels being worked out at one time.

The amount of dynamite used there in the last year was about 1 000 000 lb. a month.

The method of work is this: the drillers go ahead drilling holes, the blast gangs follow, and the steam shovel comes next. The problem that occurs to most minds at first is the excavation of the cut. A great many people overlook the fact that the excavation has to be disposed of, and one of the problems that we had to solve down there was the development of proper dumps to take care of all this excavation.

At first, of course, if there was a little hole handy, we filled it up. But there came a time when the dumping problem became serious. To get rid of 80 000 000 cu. yd. of dirt requires considerable space. We adopted four main dumping grounds. The principal one is the Pacific Ocean, and in dumping there we are doing two things — we are not only getting rid of the waste earth, but we are reclaiming waste land which will be very valuable later on. We are also building breakwaters with it, and practically all the good rock is being hauled 25 miles to go into the riprapping of the Gatun dam. So that on the whole I should think about one third of the material was being what you'd call actually wasted.

We have developed there to a great extent in the matter of churn drilling. We use mostly the Star drill or the Keystone.

To operate them we use common negro labor at 13 cents an hour. We have there something like 225 of those drills in operation. In the hard rock they are not so economical or successful. There we use the regular tripod drills. The power is compressed air. Along each side of the cut, 9 miles, we have a 10-in. air main which carries air at 100 lb. pressure. Our rolling stock consists of modern American locomotives weighing about 76 tons, and most of our cars are long wooden flats, with one side. They will hold about 20 cu. yd. each. We run them 19 cars to a train, giving us about 380 yd. a trip.

There are quite a few dump cars which are used to haul rock to Gatun dam and deliver material on short runs to various works of construction. The Ledgerwood flat arrangement necessitates long, straight tracks, so that they can't be economically used in every location.

The greatest single labor-saver developed and built there is what we call our track-shifting machine. It will throw track at the rate of three miles an hour any distance you want it thrown up to 8 ft.

In our dumps, there, we found many things. Your ideal dump would be very high, so you could unload more material with less track throwing. That is true, to a certain extent. We found the most economical height was about 18 ft. When we went higher than that we lost more time in picking up slides than we saved in extra material dumped.

Now, if I may speak a little more about the central division, I was directly in charge of construction on that, and know more about it than I do about the rest of the canal. On that we had 12 000 men, of whom 1 000 were Americans, skilled employees. The conductors and engineers on the trains and the skilled mechanics in the shop, the steam-shovel men and the foremen are Americans. Then we had about 3 000 Spaniards and Greeks, — European laborers. The average salary paid to the Americans was about $150 a month. The Spaniards and white foreigners, as we called them, — aliens, — received 20 cents an hour. We had between 3 000 and 4 000 of them, according to the labor market. The other 6 000 or 7 000 were West Indian negroes. Those men received 10 cents an hour, and the commission feeds them, if they wish, at a cost of 30 cents a day. The white Spaniard pays 40 cents for his three meals. They get a few extras. The white American pays 90 cents a day for three meals.

To handle that bunch of men requires a little diplomacy.

When I went there I found a superintendent of tracks, a superintendent of drilling, a superintendent of mining, a superintendent of steam-shovel work, a superintendent of transportation. If I asked the superintendent of steam-shovel work why his output fell off, he'd say the superintendent of track didn't get the track over there, or the superintendent of mines didn't have the shooting done— something similar is sometimes seen in some places in America. I divided the central division into five construction divisions, placing a superintendent of construction in charge of each division. He is the man who is held responsible for everything going on in his division. I wanted to put engineers on that work, but out of those superintendents I could only find one man who had the necessary experience as a civil engineer. So that, out of five superintendents to whom I paid $350 a month, I had one civil engineer. I don't suppose you care for what I think about engineering careers, but my experience has been that engineers neglect the construction end of it considerably. Of course there is no use in a man going into construction if he has no taste for it. But that was my experience on the Isthmus in trying to give away $350-a-month jobs to civil engineers. I couldn't find the engineers with the qualifications.

That division is under a division engineer, who is a member of the canal commission. Then comes the assistant division engineer, which position I held, who has direct charge of all the work. The resident engineer was held responsible for all maps; and the superintendents of construction, as they wished lines or grades, etc., simply called on him and he supplied them. He was not directly over the construction work. In fact, he acted rather in an advisory capacity, in charge of all map work and the necessary plans and profiles, etc.

That is more or less the organization of the central division. The present organization of the whole canal is based on that organization. There was a division of municipal engineering and I don't know how many other divisions down there, and Colonel Goethals decided that if the Culebra Cut could be run in districts, he could run the whole canal in districts. So that is how the three divisions came to be made up. And the division engineer has charge of everything in that district. He is responsible to the chief engineer for everything that occurs between Gatun dam and Pedro Miguel dam in the central division and so in the others. That organization has worked out very well indeed.

Outside of the engineering work, there is a good deal of work

to be done. There is a good deal of money to be handled. The pay-rolls amount to $1 500 000 a month. The disbursing officer has a large force under his command, and he pays off the whole force on the Isthmus. He reports directly to the chief engineer. The quartermaster's department is responsible for the securing of all supplies, building the necessary dwellings, etc., and securing the necessary labor force. We stopped recruiting men in Europe about a year ago. We find that the good reputation of the Isthmus has gone abroad, so that we now do not have to offer any inducements. Every boat that comes in brings laborers enough to keep our forces up. For the starting and developing of that labor force, practically all the credit is due to a man who died recently, Mr. Jackson Smith. He brought that labor force up to the high standard which it now maintains.

There is also the government of the zone, which is called the civil administration department, under another canal commissioner. They have charge of post-office, schools and police force. We have a police force there of only about 250 men to handle the whole zone, 50 miles long, with a population of 70 000 or 80 000 people. But we have there a thing which does more to keep the men in order than anything I know of, and that is the chain gang. We had, when I left there, 125 convicts in the penitentiary. To each man of this penal force is hitched a ball and chain around his ankle, and he is turned loose under armed guards on the road to break stone. And although five years ago we were troubled with an influx of bad men, one or two views of that chain gang were enough for them. They disappeared without any trouble after that. You can go into almost any contractor's camp on pay day and see more trouble than you could on the whole Isthmus. Our police officers are good men and well managed, but there is no necessity of calling on them.

The schools are run on the plan of the Massachusetts graded schools, ranging from the primary to the high school, with a superintendent of schools and something like 3 000 children.

The average temperature in the zone is about 80 degrees. That may sound strange to you for the tropics, but it is a fact. The thermometer never gets much higher or much lower. But the humidity to which this low temperature is due is very high — about 85 per cent. The effect of the tropical or isthmian climate is enervating, and after two or three years down there the blood begins to thin out, and unless a man is of a highly nervous constitution, he loses his ambition somewhat. Outside of that, the climate doesn't have any bad effect, although I noticed children

of the third generation of Americans there don't seem to have any more ambition than the natives. I am sure if people of American blood should settle there, in two or three generations they would be on about the same basis as the present natives.

In a general way, I think that about covers what I want to say. There is just one thing more. The cost of our work down there is showing up much lower than any contractor offered to look at it for, three years ago. I think we ought to feel very proud, as Americans, of the way the work has gone. I think Colonel Goethals is entitled to particular credit for the way he is carrying it on, and he ought to have a great deal more support than he has. The work has all been done by day labor. I don't believe there has been one cent of graft, so called, on the canal since the project was started. It is put up to every man to do a day's work. As long as you do that you hold your job. When you don't do it, you can get out. And no Senator or Congressman's OK is going to help you in the least. That policy has been followed up to date, and I hope it will continue to the end. If it doesn't, you will soon begin to see the work retrograde. It simply shows what the American government, or any other government, can do when they go about it on a businesslike basis. That is what the canal work shows to me to-day. The efficiency of the men and the material alone is considered, and the results are there for which every American ought to be proud. And every American ought at least to make an attempt to pay a visit to the canal before it is finished. The work will culminate this coming March, and begin to go down. February and March are delightful months to be on the Isthmus, and if Boston climate has not changed since I was a boy, February and March are delightful months in which to get away from here. I can't imagine a better sea trip. You can make the whole trip in three weeks, — a week down, a week on the Isthmus and a week back. And I am perfectly sure any of you would be fully repaid for the time and expense.

DISCUSSION.

A Member. — I'd like to ask Mr. Rourke what he meant by saying that an 18-ft. dump was an economical dump for trains. I do not quite understand.

Mr. Rourke. — On the Isthmus there is a very heavy rainfall. Sometimes you get 4 or 5 in. in an hour. We have dumps there 60 ft. high. Naturally, at first sight, you'd want a high dump in order to avoid throwing track any oftener than you

could help. But the 60-ft. dump went down and the cars went down with it, and it cost us more in the end than the 18-ft. dump which we could handle nicely, although we had to throw track oftener. It is cheaper to build a dump that way, 36 ft. high, than it would be to raise it 36 ft. all at once, on account of these slides, due to the heavy rainfall.

MEMBER. — Due to local conditions?

MR. ROURKE. — Exactly, and the class of material.

MR. F. P. STEARNS. — I notice that Mr. Rourke does not entirely agree with the eminent French engineer who wrote a paper for the London Society of Arts in the latter part of 1906, in which he deplored very much that the American engineers had put such heavy machinery on the Isthmus. He said it would not be possible to operate such machinery, and predicted that they would never obtain an excavation of more than 300 000 cu. yd. a month, although the French had done much more.

MR. ROURKE. — In the month of March our excavation was 2 065 000 in the steam-shovel division alone, and the other divisions brought it up to nearly 4 000 000 cu. yd.

MR. STEARNS. — I don't know as I have any question to ask. I had the pleasure of coming up from the Isthmus with Mr. Rourke at the same time that Mr. Stevens came up. He was not then in charge of the central division, although he was connected with it. I remember at that time, when the output was increasing, but was not anywhere near what it is at present, he outlined the necessity of having one person control the excavation, handling of trains, dumping and many other features that he regarded essential to an increase in the output. He evidently had a very clear idea of the proper organization at that time, for soon after, when he was put in direct charge of that work, the improvements he suggested at that time went into effect. And undoubtedly others have been added that occurred to him from time to time. But it was to a large extent the introduction of the improved methods which he then outlined that produced the great output from the central division of the canal.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 15, 1911, for publication in a subsequent number of the JOURNAL.]

STERILIZATION OF WATER AND DISINFECTION OF SEWAGE.

[Papers read before the Sanitary Section of the Boston Society of Civil Engineers, December 1, 1909.]

STERILIZATION OF PUBLIC WATER SUPPLIES.

By George A. Johnson, Member of the Boston Society of Civil Engineers.

The treatment of water supplies with germicides is a practice of comparatively recent origin, and the practical application of this branch of water purification covers a period of only a very few years. At first the addition of sterilizing agents to water was confined to supplies which were either under suspicion or known to be temporarily polluted, and such treatment was always abandoned as soon as the danger was past. The marked attention which recently has been given to the continuous use of germicides in connection with the purification of water supplies on a large scale leads us to consider all of the circumstances under which such treatment is necessary or advisable.

It is not the intention of the speaker to enter into a discussion of the relative merits of all germicidal compounds. He is aware of and appreciates the success which has accompanied the use in water sterilization of permanganate of potash, copper compounds, ozone and the like, but interest at this time appears to be directed particularly to the remarkable results which have attended the use of oxygenated chlorine compounds, and it is to these that his comments will be restricted to-night.

As Professor Phelps has told you, hypochlorite of lime has been used for the disinfection of sewage, experimentally or otherwise, in numerous places in this country and Europe. It was also used to sterilize the water distribution system at Maidstone, England, following an epidemic of typhoid fever at that place in 1897. Hypochlorite of soda was applied to the water supply of Lincoln, England, during and following an epidemic of typhoid fever in 1904-5. The use of hypochlorite of lime next came into particular prominence at Chicago and Boonton, N. J., in 1908, as will be referred to in detail by the speaker later on.

The publicity given to the results obtained at the two places last named served as an impetus in leading other cities to adopt its use, and at this time dozens of cities in this country are treating all or part of their water supplies with it.

Nature of the Process.

The chemical most commonly used is a high grade of bleaching powder. This chemical is a mixed salt consisting of approximately equal parts of calcium chloride and calcium hypochlorite. It ordinarily contains about 35 per cent. of what the analyst calls "available chlorine," corresponding to about 8 per cent. available oxygen.

When added to water the hypochlorite in the bleaching powder is acted upon by the free and half-bound carbonic acid which the water contains, and hypochlorous acid results. This acid is very weak and very unstable, and in the presence of organic matter decomposes and liberates oxygen in an atomic and therefore most active state. The oxygen liberated in this manner acts on the organic matter and bacteria and so destroys the latter by a process of oxidation.

The general result following the application to water of hypochlorite of lime is the destruction of the majority of non-spore-bearing forms of bacterial life; a reduction in the organic color of the water; an oxidation of organic matter proportional to the amount of the chemical applied; the total solid matter in the water will be slightly increased, as will the total hardness of the water. The differences in the physical and chemical characteristics of the water before and after treatment are ordinarily so slight as to be barely noticeable, however, and frequently are well within the limits of accuracy of the methods of analysis.

The most important chemical change which is brought about in this process is the reduction of carbonic acid in the water. The bleaching powder naturally contains enough calcium oxide to bring about this result. This point has considerable practical significance from a standpoint of the incrusting and corrosive action of water on iron and steel pipe brought about by the action of carbonic acid.

Disinfection of Polluted Waters of High Organic Impurity.

In referring to waters of high organic impurity the speaker has in mind such waters as those of Bubbly Creek, at the Stock

Yards in Chicago. This water is nothing but weak sewage, is dark colored in appearance, practically always possesses odors of putrefaction, and contains nominally between 500 000 and 1 000 000 bacteria per cubic centimeter.

Bubbly Creek, officially known as the Stock Yards Slip, derived its name from the fact that all of the time bubbles of gas cover practically its entire surface. The creek is a fork of the long notorious Chicago River. The area tributary to it at its upper end is over 17 000 acres of southeastern Chicago, and on this area there is a resident population of about 400 000 people. The sewage and street washings of three quarters of the area tributary to the creek are collected in an intercepting sewer and pumped at Thirty-ninth Street and the lake front through a 20-ft. conduit into the head of the slip. The sewage of the remaining one fourth of the area is drained into this conduit or directly into the slip at the same point through three sewers.

The 20-ft. conduit above mentioned was built quite recently in order to make possible the diversion of the sewage of parts of the city from the lake, and also, by admitting lake water into this conduit, to create a current in the Stock Yards Slip. At this time the normal gravity flow of lake water through the conduit is 30 million gallons per day. The estimated present sewage flow into the slip, corrected for ground water leakage, is about 8 million cu. ft. ~~gallons~~ per day. The estimated volume of ground water leakage in all sewers and of lake water let into the channel back of the Thirty-ninth Street pumps is also 8 million cu. ft. ~~gallons~~ per day. The station at Thirty-ninth Street and the lake front also contains two screw pumps for pumping lake water into the conduit. These are not regularly operated at this time, but have a combined guaranteed capacity of 863 million gallons per day.

It is seen from the above figures that under normal conditions, that is, when the flushing pumps are not in operation, the ground water leakage and gravity flow of lake water through the conduit will dilute the sewage of the area tributary to the Stock Yards' Slip in the proportion of about 5 to 1. When both of the flushing pumps are in operation the dilution is increased to 19 to 1. Since these pumps are not regularly kept in operation, the dilution afforded by the gravity flow of lake water is insufficient to prevent the maintenance of unsatisfactory conditions in the slip, and to-day its appearance leaves much to be desired. Under existing conditions, a regular daily discharge of about 112 million gallons (1 300 cu. ft. per second) of lake water through the conduit is necessary to prevent the continuance

of these offensive conditions. Such a volume of lake water let into the slip would dilute the sewage which now enters it in the proportion of 14 to 1.

It is rare, indeed, that the water expert is called upon to attempt the purification for certain domestic uses of so foul a water as that of Bubbly Creek. It is a case that stands alone in the annals of water purification, and in all probability will continue to occupy that position for some time to come.

The facts attending the solution of this unique problem are probably familiar to all, and the speaker will not dwell further upon the subject than to call attention to the fact that while an ample period of coagulation and sedimentation, followed by virtual sterilization with sulphate of copper and finally filtration through mechanical filters, failed to produce the desired result, the mere substitution of hypochlorite of lime, or bleaching powder, entirely altered the complexion of things. From the time the change from copper sulphate to hypochlorite of lime was made, four things were apparent, namely: First, the germicidal action of the new chemical was as rapid, certain and complete as copper sulphate; second, through the oxidation of much of the readily putrescible organic matter which the partially clarified water still contained, the odor of sewage, always noted when copper sulphate was used as the germicide, was permanently removed from the water; third, bacterial propagation in the final product was practically eliminated, while when copper sulphate was used this was a very troublesome feature; and, fourth, the cost for germicidal chemicals was reduced to about one sixth of what it was when the copper was used.

The purification plant at the Stock Yards continues to do satisfactory work. The effluent is always clear and colorless, and it is rare, indeed, that coli are found in it or that the numbers of bacteria exceed 50 per cubic centimeter. For more than a year this water has been used for stock-watering purposes at the Chicago Stock Yards.

Sterilization of Polluted Waters of High Color or Turbidity.

In the first place, it must be distinctly borne in mind that the addition of germicides to water does not to any noticeable extent improve the physical imperfections thereof. Such waters, to be made physically acceptable, must be subjected to long periods of sedimentation, or filtered, or both. All that the addi-

tion of hypochlorite to such waters will do is to destroy dangerous bacterial life. Turbid or colored waters containing dangerous bacteria may be rendered safe for drinking purposes, but in appearance they will remain unaltered by the treatment.

Sterilization of Clear Well Waters Temporarily Polluted.

Where a well has been polluted with pathogenic material entering beneath the ground, until the source of such pollution can be located and the nuisance removed, the water may be made safe for drinking purposes by the use of hypochlorite. Well waters, which are always subject to slight and unpreventable pollution, may be made thoroughly safe by applying hypochlorite to the water as it enters or leaves the pumps. As an absolute safeguard against pathogenic bacteria at any time reaching the consumers, hypochlorite is now being continuously used on a number of well supplies in this country.

Sterilization of Impounded Water Supplies.

Where waters are stored in large impounding reservoirs, and the conditions in general on the catchment area such as to allow the question to be raised as to whether polluting material reaches the reservoir, hypochlorite has a field of great usefulness. If the water as it leaves the reservoir is turbid or colored to a degree which makes it unacceptable, filtration should form a part of the purification process.

In some instances it is impossible to keep out of the impounding reservoir all sewagic matter except by purchase of the whole catchment area. Such a procedure is always costly and rarely necessary. By instituting a system of strict sanitary patrol in order to see to it that the sewage of communities is either first purified or diverted to a point below the dam, and to prevent the deposit or storage of human excreta on the watershed from which it may be washed into the reservoir or feeders at time of rains, about all that is necessary has been done.

Even by exercising such care as this to keep the catchment area clean, there are still left the washings from cultivated fields and roads which may enter the reservoir or its feeders. A chance traveler over this area may be a person suffering from the early stages of typhoid fever, or convalescent. An evacuation on the part of such a person may allow typhoid bacteria to be washed into the reservoir. It is possible, therefore, for any

impounded reservoir supply at times, under a certain combination of abnormal conditions, to become polluted. If such is the case, the application of hypochlorite to the water as it leaves the reservoir will remove all possible danger from pathogenic infection.

Such a case is found at the Boonton reservoir, where the water supply of Jersey City is impounded.

Sterilization of the Water Supply of Jersey City.

The water supply of Jersey City is derived from the Rockaway River, the waters of which are impounded in a reservoir located at Boonton, about 23 miles west of the city. The reservoir has a capacity of about 8 500 million gallons, equal at the present rate of consumption to over 200 days' supply. The water is conveyed to the point of distribution in Jersey City through an aqueduct of concrete conduit, tunnel and steel pipe.

By reason of the fact that the watershed of the Rockaway River contains several relatively large towns, — all unsewered, however, — and that much of the area is cultivated, it was thought wise to guard against the possible presence in the water as delivered of any disease-producing germs. It will be well to point out that the entire watershed is subject to sanitary patrol, but the use of a germicidal agent was inaugurated at Boonton in order absolutely to insure the water against disease-producing germs, in the event that any such organisms should find their way into the reservoir. The high sanitary quality of the water from the Boonton reservoir is abundantly shown by the low typhoid death-rates which have prevailed in Jersey City since its use was begun in 1904. For the five years beginning in 1904 the typhoid death-rate per 100 000 population in Jersey City has been 20, 19, 21, 13 and 10 respectively, or an average of less than 17 for the five years.

Since September 26, 1908, all of the water delivered to Jersey City, amounting to about 40 million gallons daily, has been treated with hypochlorite of lime with the exception of two days during which electrolytically prepared hypochlorite of soda was applied. The germicide is applied to the water at the gatehouse at Boonton as the water leaves the dam, and just before it enters the conduit to Jersey City. The solutions of the sterilizing agent are prepared and their application to the water controlled in a sterilization plant adjoining the gatehouse at the dam.

Sterilization Plant.

The sterilization plant is contained in a one-story wooden building having approximately 2 200 sq. ft. of floor space. The superstructure covers a concrete floor built above the various solution tanks and pipe gallery. The floors of the boiler, engine and store rooms rest upon an earth fill.

The storeroom has a capacity of about three carloads of bleaching powder (hypochlorite of lime), corresponding to about 45 tons. This quantity is sufficient for over seven months continous operation.

The large tanks, in which the chemical solutions are mixed and stored, are three in number, built of concrete and each has a capacity of about 9 600 gallons. The floor of each tank slopes to a sump, and a 4-in. blow-off provides means for flushing into a 32-in. steel overflow pipe extending from the gatehouse to the Rockaway River below the plant. A 2-in. suction pipe leads from just above the floor of the tanks to the turbine solution pumps located on the main floor of the building.

The small tanks, in which the dry powder is dissolved, are about 6 ft. in diameter and 3.5 ft. deep. These are built of reinforced concrete and are located within the respective large mixing tanks. Over a portion of the top of each of these dissolving tanks is a grating of 2-in. by $\frac{3}{8}$-in. steel bars, spaced on 3-in. centers, through which the dry chemical is dumped when preparing solutions. The 6-in. overflow pipe from this tank into the main mixing tank is located about 18 in. above the bottom of the smaller tank. A 4-in. blow-off in the bottom of each dissolving tank provides means for flushing out all sludge which may remain after the soluble matters in the bleaching powder have been extracted.

In each of the small dissolving and large mixing tanks suitable agitating devices are installed, the power actuating these rakes and paddles being obtained from a shaft driven by a 30-h.p. horizontal turbine wheel. Power from the same source is used to drive the special bronze pumps which raise the solution from the mixing tanks into the orifice tanks. In each of the large mixing tanks are self-registering depth recorders of the standard type furnished by the Builders Iron Foundry of Providence, R. I. The dials are 12 in. in diameter and upon the charts are recorded a continuous record of the depth of the solution in the tanks.

There are two concrete orifice tanks 3.5 ft. square in plan

and 2.5 ft. deep. The delivery pipes from the solution pumps are arranged so that the solution may be discharged into either one of these tanks as desired. An excess of solution is always pumped, such excess returning to the storage tanks through a 3-in. overflow pipe. Each tank is provided with an adjustable discharge orifice made of a special composition of copper, lead and tin. By means of a fine micrometer screw, a cover is moved backwards and forwards over a slot permitting the use of an area of opening found to give the desired volume of solution under a constant head. Any deficiency in head over this orifice is immediately indicated by a copper float so arranged as to ring an alarm gong at such times.

On leaving the orifice tank the solution flows by gravity through a 3-in. galvanized iron pipe line to the screen chamber located beneath the main floor of the gatehouse. There the main line branches into 4 lines of 1.5-in. galvanized pipe, each extending to a grid fastened over the face of each of the 48-in. mains coming from the reservoir. The grids are made up of 1-in. pipe drilled with twelve $\frac{1}{4}$-in. holes pointing downward.

Operating Procedure.

The nature of the plant is so nearly automatic that only two men are required to operate it. One of these men is competent to make the necessary chemical and bacterial tests to determine the strength of the solutions and the composition of the raw and treated water, although during the first ninety days' operation the staff included a trained analyst.

Solutions of $\frac{1}{2}$ per cent. strength are used at Boonton; that is, solutions made by adding 5 lb. of the bleaching powder to each 1 000 lb. of water. These solutions are tested as soon as prepared, to determine their strength and to make sure that no mistake has been made in their preparation, and when a tank is in use it has been the custom to test the solution as it flows to the raw water at intervals of three hours, but such frequent tests appear to be hardly necessary as the strength of the solution has been found to vary very little throughout the use of a tankful, which lasts about 24 hours.

The adjustable orifice in the orifice tanks, into which the solution is pumped from the storage tank, allows an accurate measurement of the applied dose, and whenever there is any interruption in the flow of solution through this orifice alarms are automatically rung and the trouble at once remedied. In

operation the whole plant is as nearly automatic as it is possible to make it. The daily routine of the operator is to superintend the preparation of one tankful of solution daily, the manual labor in this operation being furnished by laborers regularly employed about the dam to keep the grounds in good condition. The operator also makes a bacterial analysis of the raw and treated water once daily and also makes frequent chemical tests of the strength of the solution which is being applied. He prepares his record of the previous day's work, and is on hand to change the dose of applied chemical if any change is made in the rate of discharge of water into the aqueduct. Such changes are rarely made as often as once a day. He also keeps an eye on the water wheel and electric motor and is at hand in case the alarm gong indicates that something is wrong at the orifice tank. The operator is actually kept busy not more than one half of the time, and it is with the greatest ease that a uniform dose of the germicidal solution is applied to the water at all times.

Results Obtained.

From the first the results have been highly satisfactory. The water after treatment has always been virtually sterile, — at times, indeed, absolutely so; and coli have been found only on rare occasions in 1 cu. cm. of water tested. In fact, during the first six months' operation it was found but three times in 10 cu. cm. of water tested, although such examinations were made at least once a day. The results which have been obtained during a year's operation of the sterilization plant at Boonton show in a decisive manner that the Jersey City water supply has been made as safe for human consumption as would have been possible of accomplishment by the most carefully built and operated filtration plant.

Mention has been made of the fact that this process destroys the majority of non-spore-forming bacteria. Fortunately, such pathogenic germs as those of Asiatic cholera and typhoid fever do not form spores, and the same is true of B. coli and the majority of bacteria having for their habitat the intestinal tract of man and domestic animals. It should further be pointed out that bacteria may be present to some slight extent in minute particles of suspended matter in the water, and, therefore, protected somewhat from the action of the germicidal agent.

Cost of the Treatment at Boonton.

During the first six months' operation of the Boonton plant the total cost of the treatment, exclusive of interest charges and

depreciation, was about 14 cents per million gallons of water treated. If interest charges and a moderate charge for depreciation had been added, the total cost of the process would have been about 20 cents per million gallons of water treated. These low costs were made possible chiefly on account of the fact that the cost for power was practically nothing. A water wheel actuated by the water flowing through the pipes which deliver the water from the dam to the aqueduct leading to Jersey City furnished all the power necessary at this plant. The regular gate-man at the dam is able to attend to the small amount of additional work occasioned by the operation of the plant so that the time of but one operator is chargeable to the cost of the treatment.

Later on, in order to be absolutely on the safe side and be sure that enough of the germicide was added to the water to meet all possible conditions as regards the character of the raw water, the amount of chemical used was increased from 5 lb. to 9 lb. per million gallons of water treated. This increased the actual cost of the treatment from 14 cents to about 19 cents per million gallons, which is true of conditions as they exist at Boonton to-day. If a liberal annual charge of $1 000 were added to this figure to cover interest on the first cost of the plant and depreciation, the total cost would be about 25 cents per million gallons.

Depreciation of Plant.

As to depreciation in the plant, it may be well to point out that, although the process has now been in operation over fourteen months, it has not been necessary to replace any of the piping, pumps or valves, and such repairs as have been made are not worthy of mention.

Efficiency of Hypochlorite of Soda.

Some time after the sterilization plant was put into service, studies were begun to demonstrate the relative efficiency of hypochlorite of lime and hypochlorite of soda, the latter prepared electrolytically. A small electrolytic cell was obtained from the National Laundry Machinery Company, of Dayton, Ohio, and a quantity of hypochlorite of soda prepared. In its preparation a solution of common table salt of about 4.5 per cent. strength and of an initial temperature of about 65 degrees fahr. was used. This solution was run through the electrolyzer at a rate of about 2 cu. ft. per hour in the presence of a direct current of 110 volts

and 22 amperes. The amount of salt used was between 5 and 6 lb. per hour, and the yield of a single cell was about 0.6 lb. of so-called "available chlorine" per hour, corresponding to 0.135 lb. of available oxygen. This would be equivalent in germicidal power to about 2 lb. of bleaching powder.

A comparative test run was made for 50 hours on March 20–22, 1909, about 80 million gallons of water being treated during the run, and the results of numerous analyses during that period showed that hypochlorite of soda was quite as efficient as hypochlorite of lime. The numbers of bacteria in the raw water at this time were about 3 500 per cubic centimeter, and in the treated water as delivered in Jersey City, 13 per cubic centimeter while the hypochlorite of lime was in use, and 10 per cubic centimeter while the hypochlorite of soda was in use. B. coli was absent from the treated water at all times during this period, judging from repeated tests of 10 cu. cm. quantities of the water.

Sterilization as an Aid to Filtration.

Where waters are turbid and require filtration to render them clear and colorless it appears certain that hypochlorite can be used to great advantage. If the filters are of the slow sand type the use of hypochlorite coincident with preliminary sedimentation will lengthen the periods between necessary scraping of the sand surface through the destruction of algae growths.

Much information of a definite character is still lacking with respect to the efficiency of hypochlorite as an algæcide. Cases which have come to the speaker's attention show that it is particularly destructive to some forms of algæ. It is understood that the United States government is conducting some experiments tending to show its value in this field.

Where the filters are of the mechanical type such evidence as has been furnished by investigators at Lawrence, Baltimore and elsewhere indicates clearly that the use of hypochlorite in the preparatory process is accompanied by a very material saving in the amounts of coagulant and wash water used. In at least one mechanical filter plant, that at Cincinnati, Ohio, the use of hypochlorite at times when there were extensive growths of algæ in the raw water effected a marked extension in the length of runs between filter washings.

When hypochlorite is used in conjunction with any filtration process there is one feature which must not be lost sight of.

Filters exert no particular selective action on the bacteria they remove, and through the best of them sewage bacteria are sometimes found to pass. Hypochlorite, on the contrary, does exert a selective action, and the bacteria which yield most readily to this germicide are the less resistant non-sporing forms, in which class is the typhoid fever bacillus.

If the hypochlorite, when properly applied, can be depended upon to remove the objectionable bacteria from the water, as it appears that it can be to as great an extent, if indeed not a greater, than can any filter, then the filter of the future may be properly considered in the essential light of removing the mud, color and miscellaneous débris which the water may contain. Under these circumstances higher rates of filtration can be used, which means a material reduction in the first cost of the filters.

Cost of Hypochlorite Treatment.

One of the chief points in favor of the use of hypochlorite in the sterilization of water is its low cost. The chemical itself may be bought at present for one and one-quarter cents per pound in carload lots, and where 10 lb. are found to be sufficient to produce the desired result, as at Boonton, N. J., Poughkeepsie, N. Y., and elsewhere, the total cost for chemical is only $12\frac{1}{2}$ cents per million gallons of water treated. Where other chemicals are used in the purification process the cost of the application of the hypochlorite is almost nominal.

Hypochlorite of soda, produced electrolytically, was found at Boonton to be just as effective a germicide as hypochlorite of lime, or bleaching powder. The cost for electricity ordinarily makes it considerably more expensive than bleaching powder; but, judging from such data as are at hand, the cost of its use in water purification will always be materially lower than that of ozone and copper compounds. Where water power is available, the cost for electric current becomes practically negligible, as at Boonton, N. J., and under such circumstances the electrolytically prepared hypochlorite of soda costs about the same as the bleaching powder.

A Note of Caution.

The somewhat theatrical manner in which the germicidal purification of water with hypochlorites has come before the water-works public requires that a word be said with respect to its indiscriminate use. We have not progressed far enough to

allow us to say more than that the hypochlorite treatment has thus far been used with success on several waters of widely varying characteristics, and under a somewhat limited variety of conditions. It is not a panacea for all water ills, and it may be that the future will show it to have a much more limited field of applicability than now seems to be promised. Its application requires care and a sound working knowledge of its principles. The use of too little may be the cause of the establishment of insecure and unwarranted confidence; the use of too much may impart to the water an objectionable taste and odor; its use at all in some cases may be inadvisable. Prudence requires its application to be carefully considered for each style of problem and each variety of water. It has already proved its value in the solution of a number of problems; with proper handling it is probable that its field of usefulness will be materially broadened.

DISINFECTION OF SEWAGE AND SEWAGE FILTER EFFLUENTS.

By Earle B. Phelps, Member Boston Society of Civil Engineers.

Sewage has been described by Mr. Hiram F. Mills as a mixture of 998 parts of water, 1 part of mineral matter and 1 part of organic matter. Sewage purification refers solely to this one-tenth per cent. of organic matter, which includes also the germ-life. The complete purification of a sewage would involve the complete removal or destruction of all such organic matter, living and dead. A well-constructed and properly operated sand filter running at a low rate may approximate such a result. However desirable such results may be, the large amount of land required, about one acre or more for every thousand inhabitants, makes the price almost prohibitive in the region of large cities. Therefore the tendency of the times has been toward intensifying the natural process of purification to the end that more sewage may be treated upon a given area. Progress in this direction has been rapid and satisfactory, so that with a modern trickling filter the wastes of twenty thousand persons can be adequately disposed of upon an acre of filter surface.

With the increased rate of treatment, however, there has

come a consequent deterioration in quality. The removal of bacteria in particular has ceased to be one of the chief factors in sewage purification. To what extent pathogenic bacteria are removed by filters of coarse stone is a somewhat debated point at the present time, but it is the writer's belief, based upon many years of experimental study and the perusal of the available evidence, that the removal of pathogenic bacteria by modern processes of sewage disposal is at least not more rapid nor more efficient than that which is observed naturally in a polluted stream. In other words, the same natural processes are at work and the conditions found in the purifying mechanisms have no especial detrimental effect upon the bacteria in question. This at least is the result of investigations upon the fate of non-pathogenic bacteria of certain specific types which have been studied most exhaustively. Reference is had particularly to the bacillus coli. It has been shown repeatedly that this organism is not destroyed in modern sewage disposal plants to an extent which would have any sanitary significance. It has further been shown under controllable experimental conditions that the resistance of this organism to unfavorable surroundings — to heat, to cold, to chemical poisons, and to simple storage in water — is not much greater if any than that of the typhoid bacillus. Therefore, in the absence of any direct evidence to the contrary, it is not only just but quite necessary to assume that the fate of the bacillus coli in the various processes of sewage purification is indicative of the fate of its more undesirable relative, the typhoid germ. In summing up the evidence in this matter as presented by English experience, Houston concluded that the biological processes at work in the filters are not strongly inimical, if hostile at all, to the vitality of pathogenic germs.

Granting, then, that these sewage filters present no material barrier against the passage of bacteria from the sewage to the stream, we are confronted by a still more perplexing and unsettled question, namely, the degree of purification which may reasonably and economically be demanded. Sewage purification in the complete sense previously described leaves little to be desired as far as results go; but partial purifications of one kind or another are also possible, and in many cases may satisfy the local requirements. In brief, we can remove suspended solids, which cause offensive deposits in streams unless the flow be always rapid; we can oxidize organic matter, which will otherwise produce anaërobic or putrescible conditions in a stream unless

also the final dilution be sufficiently great; or we can destroy pathogenic germs which might otherwise endanger water supplies or shellfish beds. Finally, we can combine any two or all three of these partial methods. The adoption of a purification process fitted to the local requirements and going no further than these requirements demand, results in a twofold good. Communities installing the works are saved unnecessary expense, and more communities are finding it possible to purify their sewage, owing to the simplified processes now employed. An example has recently come to the writer's notice. A public institution secured an appropriation of eighteen thousand dollars for sewage disposal works. Plans and bids were called for and the lowest bid received called for a total expenditure of twenty-two thousand dollars, for septic tanks, special pumping apparatus and sand filters. This amount of money was not available, the appropriation lapsed, and the work was dropped for a year. A special study of the local requirements showed that by no possibility could any physical nuisance occur below the outfall. The discharge was into tidal waters, the volume of water was great compared with the volume of sewage, and the flow was sufficiently rapid at all times to prevent sedimentation. Extensive oyster beds, however, would be effected by the discharge of crude sewage at this point; furthermore, any large, floating particles would be unsightly. A system involving screening, partial clarification and complete disinfection has been designed for this institution. This system meets the local requirements far better than the first plan proposed, since special care is taken to prevent the discharge of bacteria prejudicial to the oyster beds. The total cost, including the capitalization of the extra operating expenses of the disinfecting process, will not exceed five thousand dollars.

This possibility of adjusting the character of the purification works to its requirements not only resulted in the saving of public funds but, what is of vastly more importance, made it possible to put in disposal works which might otherwise never have been installed.

This question of the desirability of disinfecting sewage and effluents has been gone into at some length because, strange as it may appear, we are better agreed at present on the methods of disinfection than we are upon its proper rôle in sewage purification work. The ever-growing necessity for some kind of sewage treatment, particularly in our larger cities, has led to the development of less and less perfect processes of treatment,

and the question of sewage disposal has curiously become less and less a matter of sanitation. The prevention of physical nuisances in our streams is now held to be all that is necessary, or, at least, all that is feasible. With the definite knowledge of new processes which make it possible at a reasonable cost to provide bacterial as well as organic and physical purification, the question is bound to arise, "To what extent shall we retrace our steps and again regard bacterial removal as one of the factors of the sewage problem?" The matter is further complicated, as it always has been, by the fact that, while the purification of water directly benefits those who pay for it, sewage purification affects directly only those communities situated farther down on the stream. It is therefore fortunate that all these matters are being placed more and more in the hands of central state bodies, boards or commissioners of health, who, looking upon the questions involved from the broad viewpoint of public policy, are best enabled to decide to what extent the disposal of sewage shall be carried out. This decision must be rendered upon the broadest of sanitary and economic considerations, and the self-interest of the individual communities must not be allowed to interfere with the general policies laid down by these boards for the public good. More and more, therefore, as the powers and activity of such boards increase throughout the various states is the opinion growing that our drinking-water streams should be protected not only from gross physical nuisances, but from serious bacterial infections. It often happens that while typhoid fever is raging in one community the next community down stream has between its drinking-water and the necessarily infected waters of the river, only a poor water filter, oftentimes broken down or greatly overworked. The margin of safety here is too small. It is manifestly unjust to throw upon any water filter the burden of purifying a stream which is being seriously and willfully polluted and infected by others. This is the position which is being taken by the more advanced of our states, as shown by legislative enactments. It is the position of the best sanitarians of the day, and finally it is the position dictated by ordinary common-sense and by an ordinary spirit of engineering caution. Therefore it does not seem that one will be charged with undue enthusiasm who holds that since it is now possible and perfectly feasible to prevent the discharge of pathogenic germs through the sewers of cities into the drinking-water supplies of other communities or upon important shellfish areas, such steps should be taken and will in the very near future be considered essential.

Let us consider now the methods by which disinfection may be brought about and the all-important matter of costs. Among the agents of disinfection, chemical and otherwise, which have from time to time been proposed, and many of which have been used in sewage work, the following may be mentioned: Heat, lime, acids, ozone, the various compounds of chlorine, including chlorine gas, hypochlorites and electrolytic products, the salts of copper, manganates, permanganates and various organic substances. In an earlier paper, the writer has considered the historical development of sewage disinfection and has gone with some detail into the possibilities and the costs of the various agents mentioned. It will be sufficient for present purposes to state that all of these agents, save the chlorine compounds and the salts of copper, are prohibitively expensive, and that of the latter two, chlorine in the form of hypochlorites appears to be by far the most economical and satisfactory disinfecting agent. Early experiments with hypochlorites in both England and Germany indicated that very satisfactory results could be obtained on a practical scale. The costs, however, of these processes were still too high for ordinary routine use as compared with the costs of other sewage disposal processes. Investigations made later in this country by the writer and others indicated that the high cost of the German results in particular was due to the excessively high standards of bacterial removal demanded. For example, in most of the experiments referred to it was thought to disinfect the sewage to such an extent that the bacillus coli would not be found in one liter of the disinfected water. Since this organism occurs in ordinary sewage in numbers ranging anywhere from ten thousand to one million per cubic centimeter, it is quite evident that the degree of purification called for in this case is far in advance of any practical requirements. Our own investigations show that it was comparatively easy to secure a reduction of total bacteria and of the bacillus coli amounting to from 95 per cent. to 99 per cent. and that beyond this point excessive amounts of disinfectant were necessary. This phenomenon of the resistant minority, as Whipple terms it, is common to all kinds of sterilization, whether it be by heat, cold, light, chemicals or other means. It is therefore decidedly more practical to determine how far disinfection may be carried at a reasonable expenditure than to attempt the ideal complete sterilization. To put the case concretely, it might be found that the pathogenicity of an effluent could be reduced 90 per cent. by the expenditure of a certain sum of money; 98 per cent. by

the expenditure of twice that sum, and 99 per cent. by the expenditure of five times that sum. The first, or even the second, proposition might develop into a feasible plan, while the last might be prohibitively expensive. From the practical engineering point of view, therefore, it is plainly our duty to achieve 96 to 98 per cent. reductions at reasonable working costs rather than to secure the ideal at prohibitive costs.

On this principle it was determined to learn to what extent sewage filter effluents, and even crude sewage itself, could be purified at costs which were commensurate with the results and with the costs of other purification processes. For this purpose, experiments were carried on at the sewage experiment station of the Massachusetts Institute of Technology for a period of over two years. Simultaneously with these investigations, work was also under way on a practical scale at Red Bank, N. J., where two hundred and fifty thousand gallons per day of septic effluent were treated. Also, through coöperation with the sewerage commission of the city of Baltimore, experiments extending over about one year were made at the experimental plant there. At Baltimore the effluent treated was from a septic tank-trickling filter system. It will not be necessary to go into the details of these various investigations, which have already been published in full in Water Supply Paper 229 of the United States Geological Survey, through whose coöperation and financial aid they were made possible. In brief, it was found that the satisfactory disinfection of a trickling-filter effluent which has been purified to a condition of non-putrescibility can be accomplished by the application of ordinary commercial bleaching powder in the proportion of three parts per million of available chlorine or approximately 75 lb. of bleaching powder per million gallons of effluent. The removal of bacteria possible in this way will average over 95 per cent., making a combined bacterial efficiency for the filter and disinfection of between 98 and 99 per cent. The cost of such a process will range from $1 to $1.50 per million gallons, depending somewhat upon the size of the plant and somewhat upon the transportation charges on the bleaching powder. Effluents of higher degrees of purity can be disinfected at still lower costs. Five parts per million of available chlorine, or 125 lb. of bleaching powder per million gallons probably represents the maximum amount which would ever be required for the treatment of effluents of a poorer quality. The disinfection of crude sewage to the same final condition as that mentioned above, namely, the removal of

over 98 per cent. of its total bacteria, may be accomplished by the application of from five to ten parts per million of available chlorine, or from 125 to 250 lb. per million gallons of bleaching powder, the amount depending upon the character of the sewage. The cost will range correspondingly from \$1.50 to \$3.50 per million gallons. The disinfection of the septic sewage required the application of from ten to fifteen parts per million of available chlorine, or of from 250 to 375 lb. of bleaching powder per million gallons. If no further purification is required than that given by the septic action and the disinfection, it will probably be found advantageous to reverse the processes, disinfecting the crude sewage before it enters the septic tank. The resulting development of ordinary bacteria within the tank is of no sanitary significance, and it is doubtless of some advantage in the subsequent purification of the organic matter in the stream to discharge an effluent rich in the bacteria which assist in that purification. The removal of the B. coli in all of the above cases is usually somewhat more complete than that of the total bacteria cited. Under the conditions of a laboratory experiment, the results of hypochlorite disinfection on the colon and the typhoid bacilli, carried out under exactly the same conditions, were identical. It seems reasonable, therefore, to assume that the viability of the typhoid germ under working conditions in practical sewage disinfection is at least no greater than that of the colon bacillus, and therefore no greater than that of the sewage bacteria as a whole. Consequently, the disinfection results obtained with the total bacteria may, in the case of chlorine disinfection at least, be referred directly to the typhoid bacillus with assurances of reasonable accuracy and of some margin of safety.

In the investigations made, the subject of electrolytic processes of treatment received considerable attention. Many such processes have been developed and a few have actually been installed. The claims of some of them are so ridiculous that the process disbars itself from scientific consideration. There seems to be something about such terms as "electrolytic" which appeals strongly to the layman, and this weakness on the part of local boards of public works has been played upon in many instances for the purpose of marketing certain patented processes of very dubious merit. At the same time there are electrolytic processes for the manufacture of chlorine which are undoubtedly successful, and in fact most of the bleaching powder which we use in this work is made by an electrolytic process

at Niagara Falls. It happens, however, that chlorine is practically a by-product of the much more important alkali industry and that its price is consequently fixed at almost the cost of materials and freight. Granting to such a process free power and theoretical efficiencies, the cost of manufacture on a scale small enough for an ordinary sewage disposal plant would still be above the market price of bleaching powder. Therefore one is not mistaken in stating that under present market conditions chlorine can be purchased more cheaply than it can be made even under the most favorable circumstances.

In conclusion, the following table of the total costs of operation, including interest on installation, is given. It is based upon a plant having a capacity of five million gallons per day, the costs being per million gallons. In general, plants of larger capacity could be run somewhat more economically, while on smaller plants the labor items might mount up somewhat faster. The costs, as will be noted, all refer to the amount of available chlorine found necessary. In this way the table can be applied to any situation after it has been determined by experiment how much available chlorine will be required to produce the desired degree of disinfection. In a rough way, the figures already given, namely, from two to five parts for filter effluents of varying quality; from five to ten parts for sewages; and from ten to fifteen or more parts for septic sewages, may be used. A special column is given to the matter of storage tanks, since in many locations this item would not be an extra charge, existing tanks being used.

Available Chlorine (in Parts per Million).	Bleach Pounds per Million Gallons	Time of Contact (in Hours).	Cost per Million Gallons.					
			Storage Tanks	Other Fixed Charges.	Bleaching Powder.	Labor.	Power.	Total.
1	25	5.0	$0.10	$0.02	$0.30	$0.10	....	$0.52
2	50	2.5	0.05	0.04	0.60	0.10	....	0.79
3	75	1.6	0.04	0.05	0.90	0.10	$0.02	1.11
4	100	1.2	0.03	0.07	1.20	0.10	0.02	1.42
5	125	0.8	0.03	0.08	1.50	0.10	0.03	1.74
10	250	0.5	0.02	0.16	3.00	0.15	0.06	3.39
15	375	0.5	0.02	0.24	4.50	0.20	0.09	5.05

DISCUSSION.

Mr. Pratt.* — I had an interesting experience with the use of hypochlorite of lime. I started in to see if I could effect a saving in the cost of operation of the plant of the Bristol & Warren Water Company by bleaching the color. Most of you know what the Kickemuet Reservoir is. The water is extremely dark colored, and, while not an unpolluted supply by any means, it is not a water of extremely high bacterial count. In other words, the control of the plant was almost entirely a question of color control. As soon as you can handle the color you can feel assured that the rest of the work is going to be along satisfactory lines, and the question of the quantity of dose is controlled by the color. When this bleach proposition first came to my attention, it occurred to me and to others with whom I was working that the bleach action might be exerted strongly enough to be able to cut the dose of coagulant and still maintain our efficiencies. The results of our experiments were that the color reduction, when using a dose of bleach 0.6 part per million, was so slight that we could accomplish no reduction in our dose of coagulants. I think that is in accord with the statement of Mr. Johnson earlier in the evening, that the color did not seem to be affected materially. The question of bacterial count was not gone into because we were getting satisfactory results with or without bleach.

Mr. Weston. — I'd like to ask whether the use of bleach in connection with the mechanical filter at the Bristol plant decreased the amount of wash water by removing algae.

Mr. Pratt. — We didn't take that point up. We ran for only a matter of about a week. Of course, as Mr. Johnson brought out, it would take some little time for the action to get completely under way to overcome the microscopic organisms throughout the whole plant.

A Member. — I'd like to ask Mr. Johnson how the treatment affects the carbonic acid in the water.

Mr. G. A. Johnson. — Of course that was such an exceedingly small quantity, comparatively speaking, that its effect must be in proportion to the amount of germicide used. But there is a certain amount of calcium oxide in this germicide and the reduction in the amount of carbonic acid in the water would be in proportion to the amount of this calcium oxide in the

* Chemist, Rhode Island State Board of Health.

germicide you use. I cannot give you any precise figures as to just what that reduction would be.

A MEMBER. — It would be a very small matter?

MR. JOHNSON. — Well, yes; but it is a matter of some significance if you can remove the carbonic acid, which you can do, and do do, to a large extent. Almost all the free carbonic acid is removed.

MR. H. W. CLARK. — Just to change the discussion around to the sewage problem for a moment, I can say that I was very glad to hear Dr. Kinnicutt speak about the work in England where bleach was added to trickling filters to destroy odors. I remember that Dr. Dunbar, of the Hamburg Hygienic Institute, did a similar work some years ago. I do not remember whether he used bleach or not, but he added a disinfectant to the sewage as it flowed to his experimental filters. This brings up another point in regard to the "resistant minority" that Mr. Phelps has just spoken about. At Lawrence we have been making many experiments for years upon the filtration of sewage that contains disinfectants. These are not experiments upon the use of disinfectants to destroy bacteria, but investigations to determine how much disinfectant of various kinds sewage can contain and still be purified by bacterial action. As far back as 1896 we operated filters receiving sewage containing arsenic, and the work has been continued ever since. Sand filters receiving sewage containing phenol have been continued in operation until the sewage contained 133.0 parts per 100 000 without checking nitrification; with mercuric chloride, 286.0 parts per 100 000; with formalin, 400.0 parts per 100 000; with arsenic, 400.0 parts per 100 000; with bleaching powder, 2.5 parts per 100 000 in connection with a sand filter and 5.0 parts per 100 000 in connection with a trickling filter. These experiments have shown very clearly the resisting power of the bacteria in the filters and their ability to continue nitrification under these adverse conditions. We have done a great deal of work during the past year or two on the treatment of sewage and the effluents of trickling filters with bleaching powder and other disinfectants. We have a lot of data on the subject but wish to get more before giving any detailed figures.

MR. PHELPS. — With regard to this matter of body temperature counts and selective action of the disinfectant, the crucial point is, Are we going to kill the typhoid germs? I recognized early in this work that this question was bound to come up and must be answered, and for that reason I made the body tem-

perature counts and determined the numbers of B. coli in all of my experiments. These experiments involved perhaps 1 000 or more tests, and as the results were practically the same with all classes of bacteria, I concluded there was no selective action. But, on glancing over my tables this evening, I note that the actual removals expressed in percentage are slightly better when based upon body temperature counts and decidedly better when referred to B. coli. To tie up these results with the really practical question of the effect of this treatment upon the typhoid organism it was necessary to compare typhoid organisms with the B. coli we had been using as test organisms. This was done on a small scale in laboratory experiments. By complete tests the fact was established that typhoid germs are acted upon by this disinfectant in practically the same way as are the B. coli. There was no practical difference. And so through this chain of evidence it is my opinion that either the ordinary bacterial count or the B. coli results will furnish a satisfactory indication of what will happen to the typhoid bacteria if any are present.

With regard to the use of more or less bleach, it must be recognized that the quality of the sewage or effluent is the most important factor to be considered in determining the amount of bleach. Raw sewage requires twice as much bleach as does our trickling filter effluent. Mr. Johnson finds that with water he can get along with only 10 per cent. as much. The amount is determined by the organic constituents of the effluent of the water, and a very slight change in the character of the one may result in considerable change in the other. The more highly purified sewage is before treatment, the less bleach it will require.

Mr. H. W. Clark. — Of course, neither Mr. Gage nor myself wishes to doubt that this bleach can kill all bacteria, both in sewage and in water, but we simply bring out the point that at Lawrence, with the water and sewage and effluents we had to deal with, we seemed to have to use more than some of the figures go to show was enough at other places.

Mr. Phelps. — With regard to this question of body-temperature counts and the possibility of there being a selective action of the disinfectant, it should be pointed out that the crucial point in all of this work is the effect of the treatment upon pathogenic bacteria in general, and upon the typhoid organism in particular. If these are destroyed, the desired end has been achieved. Our ordinary bacterial counts and B. coli determinations are employed not because they have any direct bearing

upon the general problem of disinfection, but merely because they are indicative of the results upon the less readily detectable pathogens.

It was realized early in our work that this question was bound to arise and must be answered, and for that reason counts at the ordinary temperature, and at the body temperature, as well as determinations of B. coli, were made throughout this investigation. Expressing the results in the usual form of "per cent. removed," it was found that the averages of about a thousand determinations of each kind gave values which were practically identical, whether they were based upon room temperature counts, body temperature counts or B. coli. As a matter of fact, the body temperature results were slightly more favorable and the B. coli results decidedly so.

The large scale upon which these experiments were carried out made it impossible, of course, to inoculate our filters with typhoid germs, and yet some connecting link between our practical operating results and the typhoid question was urgently needed. This was obtained by some small scale laboratory experiments. The effect of the treatment upon the B. coli had been well determined upon a practical scale and under various working conditions. Now under laboratory conditions, in bottles, the relative effect of bleaching powder in various concentrations and for various periods of time upon both typhoid and coli organisms was carefully determined in a series of parallel experiments. The results were practically identical. The effect of hypochlorite upon the two kinds of bacteria is the same. Therefore the chain of evidence is complete and in experiments, with bleaching powder at least, the B. coli results may be accepted as truly indicative of the effect upon any typhoid germs present. In general, the B. coli results parallel the total counts at room and at body temperature so that either may be employed. It is quite possible, however, that certain waters may contain an unusual percentage of body temperature spore-formers, in which case it would be obviously unfair to use the results of the body temperature counts as an index of the efficiency of the process.

With regard to the use of more or less bleach, the fact must be emphasized that the character of the water treated is the most important factor in determining the amount of disinfectant. For that reason my own published reports give limiting values only for the various qualities of sewage and effluents. The raw sewage of Boston takes twice as much bleach as does the effluent of our trickling filter, while with drinking water Mr. Johnson

finds that he needs one tenth as much. Each problem has to be solved upon its own merits, and the proper determination of the minimum amount necessary to do the work in any case requires expert judgment.

PROFESSOR WINSLOW. — I should like to say just a word. In the first place, we must all feel great gratification in having had these papers presented here to-night. The work of both speakers has been epoch-making. It seems to me, looking over the history of the subject of sewage purification, that sewage disinfection marks the greatest single step taken since the report made in 1890 by the Massachusetts State Board of Health, which has led up to all the other great developments since that time. The only fault we can find with the speakers to-night is that both have been too modest. I think the work of Professor Phelps in showing that the disinfection of sewage was a practical process is something that will open up a whole new field of sewage disposal, just as the work of Mr. Johnson enables us to deal in a novel way with the bacterial contamination of water. Sewage disinfection has a big future, not only in the case of shell-fish beds, which is perhaps the largest use at the present time, but also in communities where it is not possible to enforce purification of water supplies. Of course, the ideal method is to purify the water supply; but sometimes this cannot be done. I have in mind the Province of Quebec, where they are accustomed to use polluted river water, and where it is possible for the provincial board of health to enforce sewage purification, but not water purification. They are going to install a very well-planned disinfecting plant for the Bordeaux prison along this line. The disinfection of water marks an even greater revolution in engineering, and this whole matter of water disinfection on a practical scale is the work of Mr. Johnson, and of Mr. Johnson alone. It was he who had the courage to face the situation as he saw it. Not only did he have the courage, but he also had the skill to carry out the work, and he did it by such well-proved methods that the one demonstration of the Boonton year's experiment has practically convinced every one as to the importance of this process of water treatment. At the same time, both methods are open to misuse and must be confined within definite limits. An attempt was made in England to get rid of the organic matter in sewage by chlorine treatment. It was abandoned in the case of the Thames because while it temporarily stopped the odor, it led eventually to a stink much worse than the original one. Chlorine will kill bacteria, but

won't purify organic matter. So in the case of water purification. It is a splendid method where there are only minor bacterial pollutions to deal with. The cost is so slight that it must commend itself to thousands of communities having water supplies of fairly high quality, but not entirely free from the danger of pollution. I should not be surprised to see our metropolitan supply treated in some such way as this eventually, as sanitary standards are raised. But danger arises with a water not of such good initial quality. The chlorine gets rid of the bacteria and nothing else. It leaves all the organic matter, all the organic pollution. We don't understand what the relation of these organic pollutions is to health. But sanitarians do not recommend the drinking of sewage even though all the living bacteria have been destroyed. We do not know the effect on the human organs of various forms of organic matter sufficiently to say it is safe to drink sterilized sewage. Then there is the danger of sudden changes. If there is a flood on the watershed and a slight excess of organic matter and bacteria, a sand filter will take care of it satisfactorily, so far as we know. That is not true of the chlorine treatment. If you put in enough to disinfect the water under normal conditions, in a flood, with the corresponding increase in the amount of bacteria, your chlorine process will break down. I am personally convinced that when a sudden fluctuation takes place in the character of the water, it is difficult and often impossible to change the dose of chlorine rapidly enough to meet that condition. For that reason we must be careful not to use the chlorine process as a substitute for filtration in waters that are highly polluted, however excellent it may be for waters of an initial high character.

Mr. S. DeM. Gage. — The experiments which have been made at the Lawrence Experiment Station during the past year on the use of bleaching powder in connection with the purification of Merrimac River water were described quite fully in a paper which Mr. Clark and I presented at the New York meeting of the New England Water Works Association, last September. This paper was published in the September number of the Journal of that Association, and I presume a great many of those present have seen it, so it will be unnecessary for me to go into the details at this time. For some time we have been using bleach in connection with the operation of two water filters, one a roughing or pre-filter and the other a mechanical filter. The effluent from the roughing filter is applied to a secondary filter, in its passage to which it flows through a tank in which it receives

about half an hour's storage. A solution of bleaching powder has been mixed with the filter effluent before it enters this tank, and daily analyses have been made of the water before the disinfectant was added and after its passage through the tank. We have found that bleach equivalent to about half a part per million available chlorine must be used to insure a reduction in numbers of bacteria to a point where the disinfected water would be of the same bacterial quality as the effluents from slow sand filters operated with Merrimac River water. The cost of bleach for treatment in this proportion would be about 14 cents per million gallons. Laboratory experiments have shown that two or three times as much bleach are required to produce the same result with the unfiltered river water,

For some years we have been operating a mechanical filter with the Merrimac River water, using sulphate of alumina and soda ash, and have found that about 2 grains of sulphate of alumina and 1.3 to 1.5 grains soda per gallon are required to produce an effluent of good bacterial quality. The cost of chemicals for such treatment is about $4.80 per million gallons. The river water, while badly polluted and containing high numbers of bacteria, is usually low in color and carries relatively little turbidity, and a water of reasonably satisfactory quality, so far as appearance is concerned, can be obtained by mechanical filtration with the use of much smaller amounts of coagulants than are required to reduce the bacteria to a safe limit. During the past year the reduction of the bacterial content has been obtained by the use of bleaching powder, added to the raw water with the coagulants as it enters the coagulation basin of the filtration system. Used in this way, about 0.9 grain sulphate of alumina and 0.7 grain of soda ash per gallon in combination with bleach equivalent to about 1.1 parts per million available chlorine are required at a cost of about $2.50 per million gallons, or only about one half the cost of coagulation alone. Owing to the reduction in the amount of coagulants, the removal of color and organic matter by the combined process was less than by coagulation alone, but the filtered water would probably have been accepted by the most critical consumer as entirely satisfactory, and from a bacterial standpoint it was of much better quality than before the disinfectant was used.

The statements which Mr. Johnson made about the apparent selective action of bleach in the destruction of bacteria are of particular interest and some of the results which we have obtained may throw some light on this side of the question. As I remem-

ber it, he stated that the B. coli were eliminated in greater proportion than were the ordinary water bacteria. So far as this statement goes, the Lawrence results show the same thing; that is, with pure cultures of B. coli, or computing the elimination from the B. coli as determined by fermentation tests and subsequent confirmatory tests, the percentage removal of this type has been generally greater than the removal computed from the counts of total bacteria.

For some years we have been making counts of bacteria at body temperature in addition to the usual counts at room temperature. There are a number of reasons for making these counts in water work, the principal ones being that the results represent much more closely the numbers of bacteria which are of sewage origin than do the room temperature counts, and in addition they are available in about 18 hr., while the room temperature count requires from two to four days. Both of these features are of very practical value in the control of water purification plants, and we have come to rely on the quicker count more and more as its significance has become better understood. Applying these two counts, we have found that the effluents from good water filters, and practically all surface and ground waters used as public water supplies in Massachusetts, contain less than 100 bacteria per cubic centimeter as determined by the room temperature count, less than 10 per cubic centimeter as shown by the body temperature count and that about half of the latter will produce red colonies on litmus lactose agar. When dealing with waters and sewages which have been treated with disinfectants, however, we found that while the numbers of bacteria as determined at room temperature might be reduced to this standard by the use of small amounts of bleaching powder, quite frequently there would be no corresponding reduction in the body temperature count, and that in order to obtain a proper reduction in the latter count, a considerable increase in the amount of disinfectant must be made. Furthermore, in a great many instances, the body temperature count on disinfected waters was as high or higher than the room temperature count. This latter phenomenon has occasionally been observed with waters and sewages which have not been treated with disinfectants, but a study of the records of many thousand samples shows that the percentage of such samples having reversed ratios is very small, not over 3 to 5 per cent. On the other hand, 20 to 25 per cent. of samples of water and from 50 to 70 per cent. of samples of sewage and the effluents from contact and trick-

ling filters after treatment with bleach, yielded higher counts at body temperature than at room temperature. This abnormal ratio between the two counts is seldom noticed when the room temperature count is high, but when the room temperature count has been reduced within the limits of the standard as stated above, the abnormally high and reversed ratios are frequently observed. This was particularly noticeable in the experiments with the water filters, in which we aimed to have the effluents at least as good as the standard stated. When just enough bleach was being added to reduce the room temperature count to the required standard, many high body temperature counts were obtained, and occasionally the room temperature count would be found to be far above the standard, but when sufficient bleach was used to reduce the body temperature count to the required limit, the room temperature counts never failed to be below the standard. That is to say, we had to use more bleach when we operated the filters on the basis of the body temperature count, but we were reasonably sure that the process would not fail at times, while had we used the room temperature count alone, as is done in many places, we would have found at times that the water was not of safe bacterial quality. This question of abnormal ratios between the two counts is not peculiar to the Lawrence work. It was noted also by some of the bacteriologists who were connected with the New Jersey work which Mr. Johnson has described, and it has been observed in some other places where the bleach treatment has been tried, as I have been informed privately. In many instances where such results have been obtained, they were so apparently erratic that they were considered abnormal and were thrown out, and this is exactly the way we considered them when we first began to find them. When we worked up the statistics and found them to occur with a frequency of 20 to 70 per cent., however, we hardly felt justified in calling them abnormal or in throwing them out.

This does not in any way discredit the bleach treatment. The results of the experiments showed that it could be worked successfully, but as Mr. Johnson has said, there are many things about the process which we don't know about, and it is only by a full discussion of all such points as these that we can determine how and within what limits it may properly be applied.

In answer to Mr. Weston's question, as a general rule the amount of wash water required is proportional to the amount of coagulants used. That is to say, other conditions being equal, the period between washings and the amount of water filtered

per washing would be about doubled if the amount of coagulant were reduced one half. The Lawrence results confirm this.

In the case Mr. Pratt mentions, the principal problem was the removal of color, and when enough coagulant was used to remove the color, the bacteria were also removed. As the bleaching powder has no appreciable effect upon the color, its addition could not affect the amount of coagulants required.

It required bleaching powder equivalent to something like 40 or 50 parts of chlorine per million to obtain complete sterilization with the Merrimac River water, which is a very badly polluted water. With regard to the sterilization of sewage and effluents from sewage filters, we found in some experiments that complete sterilization was produced by 30 or 40 parts per million available chlorine, while in other cases it might take 200 or 300 parts per million to get the same result. It is apparently a question of the condition and amount of organic matter present.

The point that Professor Winslow has made as to a change in the flow or character of the water is a very important one. At present there is no way of telling how much chlorine is needed or whether the amount added is sufficient, except by the results of bacterial analysis, and this bacterial analysis requires 18 to 24 hr. for the body temperature count which I mentioned, and from two to four days for a room temperature count, which is the one usually made. After a disinfection plant has been running for some time, if a complete record has been kept of all the variations in the raw water and the amount of disinfectant required with each, it may be possible to estimate the amount of bleach to use at different times, but there is no chemical test which will indicate with any degree of accuracy how much chlorine is going to be absorbed by the water before the destruction of the bacteria occurs. The oxygen-consumed determination indicates this more closely, perhaps, than any of the other chemical tests. Experiments with many hundred samples of waters and sewages at Lawrence have shown that the amount of bleaching powder required could have been predicted within 10 per cent. in about half the samples. In the rest of the samples the amount required as determined by bacterial tests was anywhere from one tenth to one hundred times the amount estimated from the oxygen-consumed values. It may be that some satisfactory method will be devised by which the amount of bleach required can be determined in advance. If polluted waters are to be treated by this method without filtration, and the health of communities is to depend upon the satisfactory

application of this process, some such test is essential before the element of danger is entirely removed. In the process as tried at Lawrence, disinfection was followed by filtration in both cases, and a large factor of safety was introduced, as even if disinfection failed to remove the bacteria, the filter might be counted on to do its work.

A MEMBER. — I'd like to ask, in the case of the Merrimac River, what is the effect of the amounts of disinfectants put into the river by manufacturing plants? There is a bleachery and print works at Lowell and one of the largest print works in the world at Lawrence. It seems to me that the Merrimac River gets an enormous dose of bleaching powder from those sources.

MR. GAGE. — While these bleacheries turn a large amount of waste liquors into the river, the bleach contained in them is all spent bleach, that is, the active principle has been used. We make daily analyses of the Merrimac River water at the Lawrence Experiment Station, and if any appreciable quantity of disinfectant were being turned into the river, its effect would be noticed in the results of the analyses.

MR. G. A. JOHNSON. — I am very glad indeed to have heard these later data of Mr. Gage's. This is a phase of the proposition that up to the present time I have not considered seriously, and I would like to say that in connection with the work at the Chicago Stock Yards, dealing with water that was very badly polluted, we ran our culture plates at 20 degrees cent. and at 37 degrees cent. in an endeavor to establish a relationship between the numbers of bacteria which would grow at these two different temperatures before and after the germicidal treatment with hypochlorite of lime. We found, as Professor Kinnicutt has also found in his work, that the bulk of the bacteria which would develop at body temperature were destroyed, and that the bacteria which resisted the treatment were almost invariably spore-formers.

At Boonton we also did considerable work of this same general character, and the results there were in strict accord with those we secured at Chicago. In other words, there seemed to be no material discrepancy in our figures in showing that the numbers of bacteria remaining after the treatment which would develop at 20 degrees cent. were almost always, if indeed not invariably, much greater than those which would develop at body temperature; and the relative precentage reduction always greater in the case of the bacteria growing at the higher temperature. This, of course, is at direct variance with the statements made by Mr. Gage to-night.

In a paper on this subject by Messrs. Clark and Gage, read before the New England Water Works Association last September, if we accept *average* results, the point under discussion is not clearly proven. For example, it was shown that in the coagulating basin at the Lawrence Experiment Station during the period when no hypochlorite was used (1907–8) the average percentage removal of bacteria growing at room temperature was 64.1, as against 61.2 in the case of bacteria growing at body temperature. When the hypochlorite was used (1908–9) these removals became 99.3 and 93.9 respectively. During these same periods the removals by coagulation, sedimentation and filtration were 97.9 and 94.6 per cent. respectively of low and high temperature bacteria when the hypochlorite was not used, as against 99.6 and 98.9 per cent. respectively when it was used. Furthermore, without the hypochlorite the coagulating basin effluent always contained B. coli and the filter effluent contained it 13.9 per cent. of the time. When hypochlorite was used, only 1 per cent. of the coagulating basin effluent samples contained B. coli, and it was found in less than 0.5 per cent. of the filter effluent samples.

If average results do not clearly seem to prove the point Mr. Gage brings out, and many individual comparisons are in favor of his point of view, I am wondering whether it is possible that he has a particularly peculiar bacterial flora to deal with. I think we all will watch his future results with a great deal of interest, for I am sure that more careful work has been done at Lawrence than at any other water and sewage laboratory in the country. The main point at issue, of course, is the character of these organisms which finally resist the germicidal treatment. If they are non-pathogenic, it doesn't make much difference. If the typhoid germ is destroyed, — and of course we require specific data on that point, — that is all we really are after.

The point has been raised a number of times to-night, by both Mr. Clark and Mr. Gage, that it seems to be necessary to use higher quantities of this germicide than have been used with considerable success elsewhere. It seems to me this is a point of some importance, but to a practical water-works man it doesn't make a great deal of difference whether he pays 25 cents a million gallons or 75 cents a million gallons to destroy all the dangerous bacterial life in the water he has to treat. The main thing is to kill the bacteria at the least possible cost, and it can be done by means of this germicide apparently at a cost probably not one sixth of what the operating cost of a filter plant would

be, and surely not more than one tenth of what the total cost of water purification by any filtration system should amount to.

Prof. L. P. Kinnicutt. — I am under a decided disadvantage this evening, and perhaps all of us are, for we have listened to two men who certainly know more about the subject under discussion than any other men in this country. Mr. Phelps deserves the credit of having first shown that sewage effluents could be disenfected by chlorine at a cost that makes the treatment practicable for sewage plants, and Mr. Johnson was the first man to show that it was possible to sterilize water on a large scale at a very small cost by the addition of bleaching powder. It is therefore with a great deal of diffidence that I rise to speak at this time.

I am also under another decided disadvantage, inasmuch as from what I have heard whispered around this table we are not to discuss to-night whether it is chlorine or nascent or potential oxygen that is the sterilizing agent; but I suppose I may be allowed to say that as far as the action on the water itself is concerned, chlorine seems to have the same action as ozone. That is to say, chlorine will not affect the amount of organic matter in the water, will not remove to any extent the color of the water, and the only chemical action it has on the water is the adding to the water of a certain amount of calcium chloride. Ozone, also, does not change the color of the water, does not affect to any extent the amount of organic matter in the water and only differs in its chemical action on the water in that it adds no foreign solid matter to the water. The action of chlorine and ozone on the water is therefore very similar. It also seems that both chlorine and ozone can only be used successfully with the same class of waters, namely, with clarified waters of low organic content. There seems also to be another use for bleaching powder in sewage treatment besides sterilizing the effluents as spoken of by Mr. Phelps. In sewage treatment, when using the septic tank in connection with contact beds and sprinkling filters there are often, as you all know, very obnoxious odors given off into the air. Dr. Rideal in a recent paper advocates the addition of bleaching powder to septic tank effluent before running the effluent on to contact beds and sprinkling filters. In one of his late papers he has shown that chlorine has, what has already been noted in this country, a selective action, acting much more readily upon bacteria which develop at blood heat than upon the water and soil bacteria, and that the treatment of the septic tank effluent by bleaching powder does not at all

interfere with the bacterial action of the contact bed or sprinkling filter, while it does prevent a nuisance arising from the odors from the septic tank effluent.

The earliest experiments that I witnessed regarding the disinfection of water were in England during the Boer War. At that time typhoid fever was killing off a great many more of the British soldiers in South Africa than were the Boers, and consequently the disinfection of water supplies for the army was one of the leading sanitary questions of the hour. Many schemes were proposed; one was that an apparatus for heating water should be carried on mules and that all the water should be boiled before it was given to the soldiers. This, of course, was practically impossible. Then it was proposed to carry a chlorine generator on the backs of mules and sterilize the water by chlorine. The amount of chlorine that was said to be required for sterilization was very excessive in view of recent experiments. It was claimed that at least one gram of chlorine must be added to one hundred gallons of water, that the water must be allowed to stand five minutes and then the excess of chlorine removed by the addition of sodium sulphite. It might be said in passing that one gram of chlorine to one hundred gallons of water is equivalent to about 20 lb. of chlorine to 500 000 gallons of water. The most practical proposition was the use of tablets containing iodide and iodate of potassium. This plan was proposed by Lieutenant Nesfield, and the method he proposed was as follows: That three different kinds of tablets should be provided for the use of the army; one was a two-grain tablet of iodide and iodate of sodium, the second was a two-grain citric acid tablet, and the third was a two-grain sodium sulphite tablet. His experiments showed that if the two-grain iodide and iodate tablet and the two-grain citric acid tablet were added to four gallons of water, iodine was set free and complete sterilization was obtained in one minute. The two-grain sodium sulphite tablet was used to remove the excess of iodine after sterilization had been effected. This method I have tested, and I have recommended the use of these tablets to hunters and campers. These reminiscences are only spoken of this evening to show what an advance we have made in the last ten years, regarding the sterilization of water and we are to be congratulated that the best work on this subject has been done by two of our own associates.

[NOTE. — Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 15, 1911, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

Edwin Peleg Dawley.

MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

EDWIN PELEG DAWLEY, a prominent civil engineer of Providence, R. I., died October 7, 1910, after a brief illness.

He was the son of Peleg and Lucinda W. Dawley, born at Providence, R. I., October 1, 1853, where he received his education in the public schools and at Brown University, being a member of the class of 1874. He began his professional career in the Engineering Department for Water and Sewer Construction of the city of Providence, where he served about seven years.

In 1879 he accepted the position of engineer and superintendent of the Interstate Telephone Company, having charge of the construction of its long-distance line between Boston and Providence. His work and ability brought him in contact with and claimed the attention of the officials of the New York, Providence & Boston Railroad, who offered him a position in its engineering department. He was appointed assistant to the chief engineer in 1882, and subsequently, on the death of the head of the department, was advanced to that office.

Early in his railroad experience Mr. Dawley showed marked engineering ability in the solution of the many problems involved in the extensive improvements and developments which were undertaken by the railroad company in the next decade, notably the improvements of roadbed and strengthening of bridging for the constantly increasing and heavier traffic, abolition of grade crossings, four-tracking Pawtucket to Providence, etc., and the passenger and freight terminal facilities at Providence.

In 1892 the New York, Providence & Boston Railroad passed to the control of the New York, New Haven & Hartford Railroad, by which latter company Mr. Dawley was retained as division engineer. In 1903 he was made assistant chief engineer and in 1905 engineer of construction, with offices at Boston and Providence.

Perhaps the foremost of Mr. Dawley's engineering monuments was the design and construction of about a mile of double-

track tunnel, and its approaches, through the East Side hill in Providence, which affords direct connection of all the railroad company's electrified lines on the east side of Narragansett Bay, with the existing terminal improvements, and completed the last link in the chain of railroad terminal facilities in Providence which has been in progress for nearly twenty years. A professional paper on this subject was presented by him to the Boston Society of Civil Engineers in the spring of 1909.

On April 1, 1909, he resigned his position with the railroad company after twenty-seven years of the most active service, and opened an office in the Banigan Building, Providence, as consulting engineer. Although he had not been long in private practice, Mr. Dawley had been engaged on several important pieces of work. He was consulting engineer for the commission appointed by the city of Pawtucket to work out a plan for eliminating the grade crossings in Pawtucket, plans for which had been completed but had not been acted upon at the time of his death. He had also designed and nearly finished a storage reservoir dam in Smithfield, R. I., for the Woonasquatucket Reservoir Company. This dam is about 2 300 ft. long, 800 ft. of which is of concrete. The height of the dam is 32 ft. at its highest point. The flowed area is about three miles long and two thirds of a mile wide, and is estimated to hold 7 500 000 000 gallons.

Mr. Dawley was twice a widower and thrice married; in 1880, to Mary H. Bliss, by whom he had two children; in 1888, to Florence N. French, by whom he had one child; and, in 1906, to Mrs. Maud C. Freeman, who survives him, as well as the two sons, Howard and Earl, and the daughter, Mrs. Lewis Ford.

Mr. Dawley was a man of genial disposition, high ideals, unwavering integrity and exemplary character, who gave himself to his arduous professional duties with tireless energy and unflagging zeal.

He was a member of Harmony Lodge, A. F. & A. M., Calvary Commandery, Knights Templars and the Scottish Rite. He joined the American Society of Civil Engineers on April 1, 1885, and the Boston Society of Civil Engineers on May 19, 1909.

George B. Francis, }
Otis F. Clapp, } *Committee.*

George L. Vose.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVI. FEBRUARY, 1911. NO. 2.

THE COSTA RICA VOLCANOES, AND THE EARTHQUAKES OF APRIL 13 AND MAY 4, 1910.

BY T. A. JAGGAR, JR.*

[Read before the Boston Society of Civil Engineers, October 19, 1910.]

SOON after the the news of the destruction of Cartago in Costa Rica reached Boston, officers of the United Fruit Company invited the Geological Department of the Massachusetts Institute of Technology to make an investigation, on behalf of the people of Costa Rica, as to the causes of the disaster that resulted from the earthquakes. It seemed preëminently appropriate that an engineer should take part in such an expedition, and Professor Spofford consented to go himself, so that the results of this particular earthquake investigation have an engineering interest; it is the writer's task to outline the events which led up to the disaster, and to describe briefly the geology and physical geography of Costa Rica, by way of introduction to the more technical studies of earthquake damage to buildings made by Professor Spofford. From the human standpoint, the earthquake problem is primarily a construction problem, and there are very few earthquakes so severe that well-made buildings of wood or reinforced concrete would not largely resist them.

Thanks to the courtesy of the United Fruit Company, our journey extended to other republics in Central America, and to Jamaica, in order that we might see what other places were doing in the way of earthquake-proof construction, and

* Professor of Geology, Massachusetts Institute of Technology.

how the whole of Central America is divided with reference to earthquake belts. We are indebted not only to the Fruit Company, but also to a number of business men, public-spirited citizens of Boston, who contributed the funds for our living expenses during the term of this journey.

We started from New Orleans, and traversed the Gulf of Mexico and the Caribbean Sea to Costa Rica, landing at Limon on the east coast. (See map.) Going thence inland by rail,

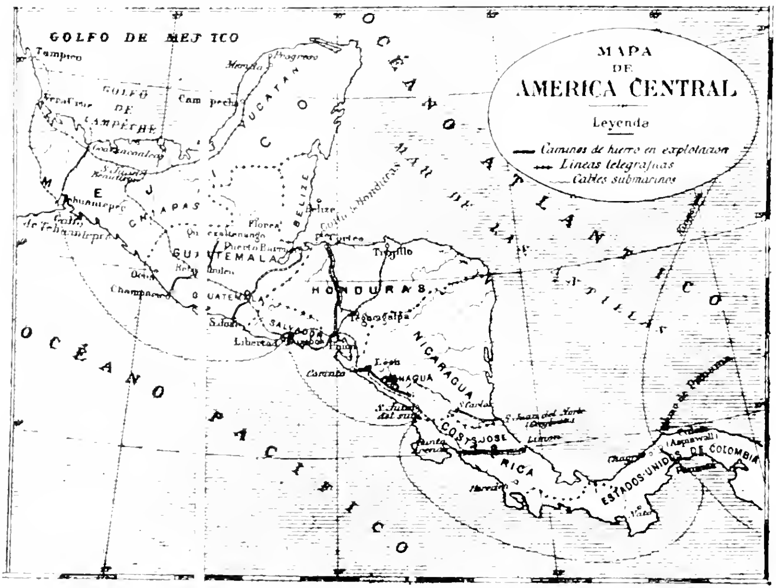


FIG. 1.

we spent some weeks in the vicinity of the capital city, San José, near the ruins of Cartago, and made excursions to the craters of the high volcanoes, Irazu and Poas. Returning to Limon, we sailed north to Barrios on the east coast of Guatemala at the head of the Gulf of Honduras. Then we crossed Guatemala by rail, stopping at Guatemala City and making some side excursions among the Guatemalan volcanoes. From Guatemala we traveled south to Panama on one of the Pacific mail steamers along the Pacific coast of Central America, seeing Salvador and Nicaragua *en route*. We were hospitably entertained by the Canal engineers in the Panama Canal Zone, and crossing the isthmus, we took ship to Jamaica, where we spent a few days studying the methods employed by the British

government to rebuild the city of Kingston of earthquake-proof structures. We were there entertained by Mr. Herschel, government surveyor in charge of the inspection of buildings. From Jamaica we returned to Boston about the middle of July, in one of the vessels of the United Fruit Company.

Such was the journey in outline. The main object of it was the study of earthquakes and their effects, and of methods of prevention of disaster in earthquake countries. In seven weeks we made five separate voyages, and four of these were in splendid boats of the United Fruit Company. We were greatly impressed by the work of this company on land and sea throughout Central America and the West Indies, and its influence in the promotion of the welfare of these countries.

On the shores of British Honduras one sees distant mountains and a low coastal belt of banana lands which appears to be part of a continuous elevated reef along the eastern Central American coast. There is more evidence of recent warping up of the coast along the Atlantic shores of Central America than on the Pacific coast, and the effects of elevation are shown not only in raised beach lines, but also in revived drainage which has cut deep gorges beneath the level of former valley bottoms. We were piloted among coral keys to the harbor at Belize, where we landed for a few hours, and were greeted with heavy tropical showers.

An interesting earthquake monument in Belize is the old English church, around which there is an iron picket fence with brick posts. On one side of the church the posts all lean out in somewhat the attitude of the ribs of a Japanese parasol upside down. Careful examination of the old church and the masonry of the posts showed clearly that this displacement of the fence was occasioned by some ancient earthquake. There are the scars of rebuilding and displaced irons and bricks in the lower part of the posts. The inverted parasol effect was largely on one side, — that is, it formed a semicircle about the church.

The port of Limon in Costa Rica has been cleaned and improved largely through the efforts of the United Fruit Company, much in the same way that Panama has been remodeled by the United States government. The town is well drained, vegetation has been cut back from the inhabited districts, and close attention has been given to the breeding places of the malaria mosquito. The place was a hotbed of fever a few years ago, but it is now said to be relatively healthy. Limon is full of shipping, and there is much excellent modern construction

about the wharves and warehouses. We landed May 29, and the weather at Limon was very hot and humid. It is a tropical place, and the peasant population consists almost exclusively of Jamaica negroes imported to work in the banana lands. They stand the climate better than any other race, and can live right in the swamp lands where others would inevitably succumb to the various fevers of that enervating climate.

The buildings of Limon are very largely of wood, and at the time of the earthquakes were very slightly affected. The earthquakes were felt at Limon, but no damage was done. It may be well to interrupt the thread of this narrative for a moment in order to outline the history of the earthquakes of the spring of 1910.

Many earthquakes in the interior of Costa Rica have been reported in the last fifty years, and in 1888 a considerable shock took place near the town of Alajuela, a few miles west of San José. Since that time the country has quieted down, and the last five years have been particularly peaceful from a seismic point of view. In January, 1910, the volcano Poas, one of a chain of cones in plain view from the city of San José, broke into eruption, and scattered ash and mud over the country. On the 13th of April, 1910, a totally unexpected earthquake shock struck the capital (San José) at midnight and wrecked a good many buildings, though there was practically no loss of life. Buildings were so shaken they had to be condemned, and the center of the shock appeared to be in the southeast part of the township of San José. These towns are largely made of adobe, with walls faced with stucco. There is also much brick construction, and, living in these masonry buildings, the people became alarmed, particularly as the aftershocks were numerous. Rich and poor alike immediately went out to live in open places, shacks and tents being erected everywhere, the whole populace fearing burial within the masonry walls of their homes. Those few who lived in frame houses felt more secure. In the Alajuela district the lesson had been learned in 1888, and most of the farmer folk there live in wooden bungalows.

During the last half of April the after-shocks of this earthquake gradually diminished, and the people of San José and Cartago twelve miles to the east were just beginning to recover confidence when a frightful earth movement, about six o'clock in the evening of the 4th of May, shattered the city of Cartago to a heap of rubble. Cartago lies on the intramontane plain between Irazu volcano and a high range of mountains, of the

Rocky Mountain type, which lies to the south of the broad valley plain in which all these cities are built. All of the most densely inhabited part of Costa Rica is in this plain both east and west of the continental divide. The continental divide lies midway between the cities San José and Cartago, these two being the largest of some six or eight inhabited centers. On the 4th of May small shocks had been very frequent from one o'clock in the afternoon on, and in Cartago the people were alive to the danger, so that there was less loss of life than would otherwise have been the case. The great shock was described as coming like the snap of a whip. It came so suddenly that people were caught at their supper tables and the houses fell right in on them. An American who was a conductor on the railroad occupied a new brick house, where he was at supper with his wife. The maid had just entered the dining-room, and when the shock came she was hurled forward, and the others with her instinctively threw themselves under the dining table. They were all saved by the table. The whole house fell in on top of them, and they were rescued, but only by laborious digging. Many people were caught on the sidewalks by walls falling on them so quickly that there was no time to step aside. The greater part of the loss of life — there were some seven hundred people killed, and five hundred wounded, out of a population of perhaps eight thousand — was among infants and invalids and domestics, people who for one reason or another were confined in the houses; fortunately the greater part of the population was out-of-doors, and, had the shock not come during the supper hour, the loss of life would have been still less.

In the succeeding weeks there were after-shocks that gradually diminished in number. We arrived on May 31, twenty-seven days after the disaster.

Returning to our itinerary, we left Limon by rail on the morning of May 31, and proceeded northward along the beach for some distance before turning inland across the swamp. The railroad rises rapidly in the interior, following the general course of the Reventazon River, a torrential gorge, crossed in many places by steel bridges. As one travels into the interior, the verdure changes from that of the tropics to that of the temperate zone. At the same time the native population and the agricultural produce change, the peasants of the interior being Latin Americans, and the crops corn, potatoes, beans and coffee, in cleared farms amid forested mountain scenery. The Cartago plain (Fig. 2) and the continental divide are at an elevation of

5 000 ft. above sea level. The slopes of Irazu volcano rise from the plain so gradually that it seems incredible, as one sees it from Cartago, that that gentle bushy slope, verdant with well-tilled farms, is a great volcano rising to an elevation in the vicinity of 12 000 ft. and the highest volcano in Costa Rica.

This is the fertile agricultural country of Costa Rica. The population of Costa Rica is about 360 000 and of San José, the capital, 30 000; the national debt is about $20 000 000. There is practically no internal market. The coffee is mostly grown by foreign capital and shipped to London, where a fancy price is paid for it. The area of Costa Rica is about 18 400 square miles, and of this four fifths is still a rich wilderness awaiting the energies of a new race of immigrants. Cartago was the market town in the center of the interior agricultural district. Limon, on the coast, is the center of the tropical banana culture.

Cartago was built, like most of the larger interior towns of Central America, of stucco-faced masonry houses made of mud or brick and mostly roofed with heavy tiles. It is impossible to tell, when these buildings are in good condition, what they are made of behind the stucco; but when the disaster came the relatively large proportion of brown adobe appeared in the tumble of ruins.

We reached the station of Cartago on our way to San José and were amazed at the suddenness of the transition from a countryside totally unaffected by earthquake to a city completely demolished. It is true that the town of Paraiso next east to Cartago was almost equally affected, but the country dwellings a short distance outside of these towns, even when made of adobe, were frequently hardly cracked at all, showing that the shock of high intensity was limited to a very small area.

Cartago was a complete wreck; here and there a building rose above the general ruin, but close examination showed it to be cracked and riven in every direction. The only building near the railroad which appeared uninjured was the frame station, an ordinary wooden building with corrugated iron roof. The station appeared to be quite intact, though when one came to examine the interior, the plaster was cracked and flaked off and had to be replaced.

The earth wave, studied from a geological standpo nt, was peculiar in the dominant vertical movement of the earth. According to the accounts of those who experienced it, it must

FIG. 2. CARTAGO VALLEY.

Fig. 3. A Vault in Cemetery riven by vertical shock.

Fig. 6. Bomb of January 25, 1906, dug from hole in edge of Crater of Poas.

have been much like the shock felt in the region of the epicentrum of the Charleston earthquake of 1886. In the town of Summerville, west of Charleston, the wave emerged nearly vertically, so that mantels were driven into the ground and chimneys telescoped. Some such wave must have emerged at the surface about midway between the cities of Cartago and Paraiso. The earth wave was singularly limited in view of the amount of damage accomplished. It is always difficult to compare earthquakes with reference to intensity because the effect on human property is an inadequate measure of intensity. The quality of mortar and building customs may have more to do with the results than differences in intensity of shock. That the wave emerged vertically in places is shown by cone-shaped breaks and symmetrical splitting of arches in some of the monuments in the cemetery. (Fig. 3.) The great parochial church, made of heavy andesite blocks in Norman arches, was displaced at a point about 5 ft. from the ground, and one of the arches in a wall which trended east and west, was narrowed at the base so that the arch opened above and the keystone dropped several inches and became wedged. Apparently the ground under the whole building was actually shortened as the wave passed from east to west. There was much evidence that the major movement came from the east in Cartago, as buildings lurched in that direction, gateposts were thrown down towards the east, and along the north-south roads the western walls were thrown into the roads and the eastern walls were thrown away from the roads into the fields. These walls are much like our New England stone fences, and consist of blocks of old lava. We found them overthrown only to a distance of about one mile north from Cartago, while beyond that point little damage was done. At greater distances, however, as in Tierra Blanca, on the high slopes of Irazu, there were recurrent zones of damage. In general, however, the actual disastrous effects were singularly limited to the immediate vicinity of Cartago and Paraiso.

There were peculiar twists given to monuments in the cemetery — rotary movements about a vertical axis. This is very common in earthquakes.

The effect on the people was like that of all great earthquakes, horrible in the extreme. As the disaster came in the evening, and telegraph, telephone and railroad communication were cut off, it took many hours to get help from San José. Rescue parties began to come, in the darkness of the night, and these attempted to dig out the wounded from the ruins. In a few

days the work of rescue was systematized, a committee of safety was organized, the Red Cross Society established a hospital, bodies were buried by cartloads, and the unidentified dead were spread out for identification. One of the peculiar methods of sepulture of Costa Rica is to build elongate niches in vertical walls, like a beehive, and wall each cell at the end of the niche. The earthquake threw down the facing of many of these tombs, revealing a grewsome spectacle of rotting coffins and exposed skulls. The work of the committee of safety was efficient. Cartago was quickly restored to order, disease was prevented, and when we arrived, the city was perfectly quiet, there was no visible suffering of any kind; shacks and tents had been put up for the refugees; there was a soldier at every street corner acting as a sentinel; a relief line was being given bread at the market-place; and the streets were tolerably clear of rubbish. Had a railroad track been laid through the town, and all the fallen brick and adobe carried away, the excessive dustiness of the city would have been stopped sooner, and the work of rebuilding and recovery of property facilitated.

We made an excursion to the summit of Irazu volcano with a view to finding out whether any unusual happenings had taken place at the old crater. Don Ricardo Jiménez, President of the republic, placed at our disposal a ranch where he maintains a large cattle establishment, and, owing to his kindness, we were comfortably housed at an elevation of about 9 000 ft. above sea-level. A guide and horses were also furnished by the President, and at his direction, Dr. Anastasio Alfaro, director of the Natural History Museum in San José, accompanied us. We owe to Dr. Alfaro a debt of gratitude for his kindly assistance throughout our stay in Costa Rica.

The road from Cartago up Irazu is a muddy, steep trail, fit only for ox teams and riding animals, and the abundant tropical rains of the summer time made the road in places almost a quagmire. Nothing is so much needed in Central America, for commerce and education, as good roads.

San Juan ranch, the cattle farm belonging to the President of the republic, is a wonderfully beautiful place. The climate is that of a perpetual springtime, and the landscape is like some of the paintings of Doré or Corot — immense trees with cauliflower-like foliage, broad pastures and large-eyed cattle. The temperature is cold at night, corn and grain and potatoes are grown on the hill-slopes, and there is nothing to suggest proximity to the equator. In the buildings were two concrete silos,

and modern milk apparatus imported from Vermont was used in the dairy. One hundred Jersey cows are milked, night and morning, in an open shed. There is no necessity for ever enclosing them, and they are at liberty to graze all day and again all night. On June 3 we started on horseback for the high summit rim of the crater of Irazu. The way led through open groves, and at an elevation of about 10 000 ft. we passed the tree line and came upon a region of low shrubs and barren volcanic sands. The view at sunrise was extensive, the Atlantic showing far to the east, and the loom of the Pacific to the west. Costa Rica is a mountainous land, these volcanoes forming a line of cones which extend northwest to southeast, and probably follow a fissure in the ground which they have long since filled and buried under their ejections. The Cartago earthquake was probably occasioned by some shifting of the walls of this great fissure at its southeastern end. To the south across the great valley the Cordilleran chains appear, consisting of old rocks, partly volcanic and partly sedimentary.

The crater of Irazu appears to be the terminal hollow in a great cinder cone, once nearly filled with lava. The old lava filling has broken down on the north side, leaving two terraces of lava, one above the other, like gigantic steps on the inside of the crater below its southern rim. These represent two different stages of level of the old lava filling. On the north side of the interior of the crater there is an inward tumble of great lava blocks, the fissures between which have been partly opened into explosion cavities; these are seen in six or seven places as interior craterlets which lead down into holes extending to unknown depth. On the north side of the mountain there are sulphur banks through which visible vapor, probably mostly steam, is ejected from time to time. These solfataras were entirely quiet on the occasion of our visit.

To the east of Irazu is the high picturesque cone Turrialba, while west of it and lying nearly north of the city of San José, is the low, broad, truncated crater basin of the volcano Barba. Next to the west comes Poas, which is the most active of these cones. Irazu is 11 326 ft. high, and Poas 9 508 ft. above sea-level. The five or six important towns of Costa Rica, such as San José, Cartago, Paraiso, Heredia and Alajuela, lie in a broad valley south of these volcanoes. The valley is continuous on both sides of the continental divide. The divide is a low saddle between Cartago and San José. South of this valley, the bottom of which is really a broad, rolling plain, there is a serrate forest-

clad mountain range which has no volcanic craters and contains folded strata of fossil-bearing limestones and other sedimentary rocks.

We found a few fresh looking fissures in the ground trending west northwest — i. e., in the direction of the volcanic chain — in the cinder slope on the south side of the summit of Irazu. Possibly these cracks were made by the crustal movement which occasioned the Cartago earthquake, but Mr. Alfaro did not think them unusual or wholly new. In general, the crater of Irazu showed no evidence of renewed volcanic activity sympathetic with the earthquake.

We returned to San José, and, thanks to the kindness of President Jiménez, a *questionnaire* which we had prepared on the basis of the Rossi-Forel scale of earthquake intensities was printed and sent out to officials with a view to getting reliable data from all points in Costa Rica as to what the intensity of the shock was as measured by the effect on common objects. President Jiménez took much interest personally in the investigation of the earthquake, and showed himself fully alive to the importance of doing everything possible to relieve the temporary stress that had come upon his people, and to prevent, by proper construction, a recurrence of the disaster in the future.

He proposed that an American corporation might rebuild Cartago, and he put this proposition in writing in a letter which he sent to me after we reached Boston. It is a very fair proposal, namely, that an American company secure $2 000 000 and send their representative to Costa Rica to administer the disposal of this money, the money to be lent through the government to interested parties for the rebuilding of individual homes in the city of Cartago; the government of Costa Rica to give treasury bonds bearing 8 per cent. interest for all moneys so lent; the interested parties to give a first mortgage to the government bearing 8 per cent. interest and 4 per cent. in addition as an amortization rate, which would pay off the whole loan in a little over fifteen years. Interested parties would thus pay 12 per cent., the government would give an 8 per cent. bond to the lender, and the lender along with a representative of the government would control the nature of the building, its materials and its insurance; moreover, the lender could, if it were so desired, act as contractor for the building, and thus secure a builder's profit as well as the interest on the loan.

This proposition has been placed before contractors in the United States and is being considered seriously by a firm in

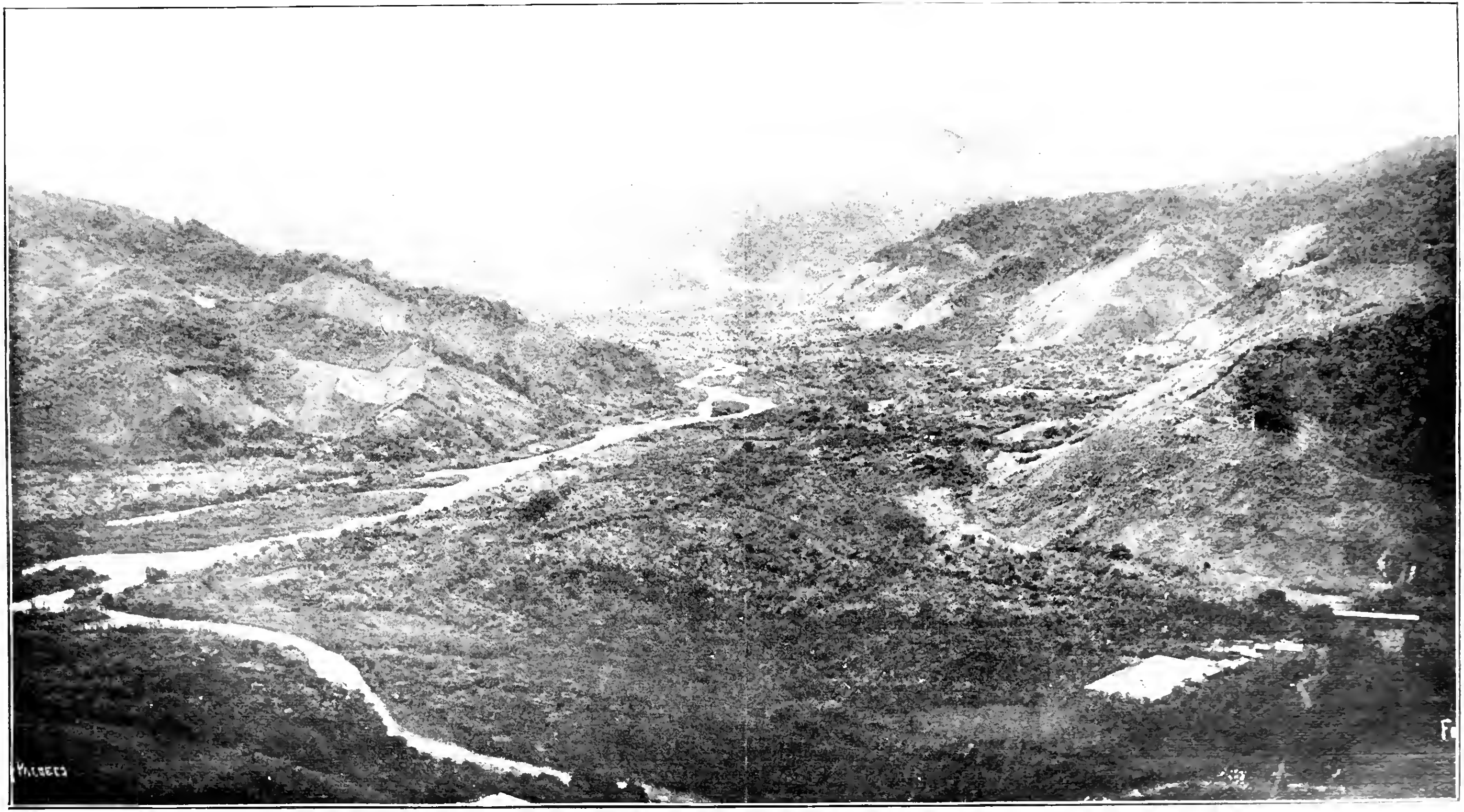
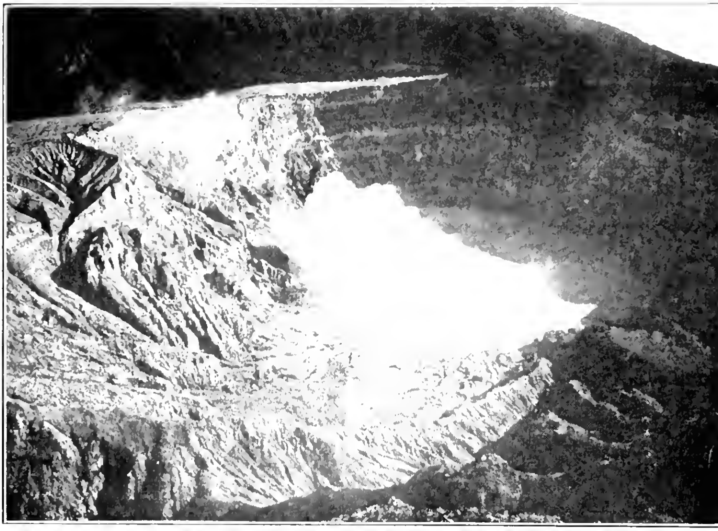


Fig. 4. In the Coffee District, Costa Rica.



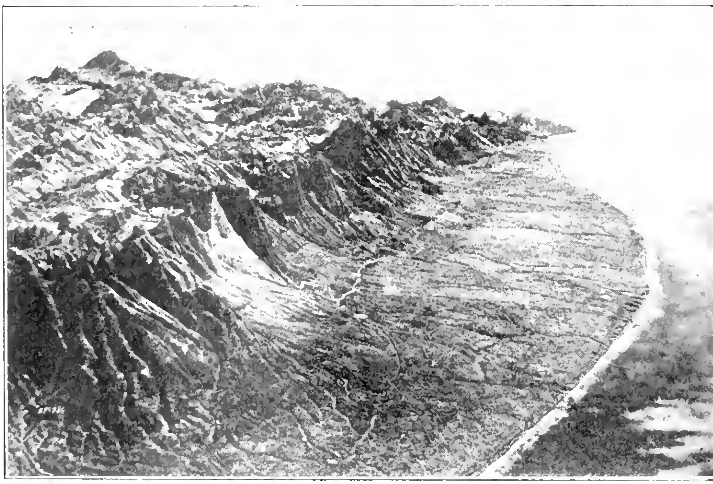


FIG. 6. MAIN CRATER OF POAS, LOOKING NORTH.

FIG. 7. RELIEF MODEL OF PACIFIC COASTAL PLAIN OF GUATEMALA, LOOKING SOUTHEAST, SHOWING CRATER OF SANTA MARIA MADE IN 1902.

FIG. 8. ASH-COVERED SLOPE OF SANTA MARIA VOLCANO, 1902.

Springfield. It would give any company that undertook the work a very vital control of an important Costa Rican city in the heart of the coffee district. (Fig. 4.)

The last excursion which I made in Costa Rica was to the crater of Poas volcano. Professor Spofford was engaged in investigations of buildings in Cartago at the time of this expedition. Accompanied by Mr. Alfaro, I went by rail to Alajuela, on horseback thence to San Pedro, and after spending the night there in the house of a friendly blacksmith, we started at four o'clock in the morning on horseback for the slopes of Poas. It was a very unlucky day for the writer, begun with an unfortunate episode occasioned by a bucking bronco, and finished with one of the worst thunderstorms of the tropical rainy season, lasting all the afternoon. The trail up Poas passes first through the farming lands where the people have had their earthquake lesson and learned to build wooden houses. This is a result of the Alajuela earthquake of 1888. We passed through high mountain pastures, where a few herders keep milch cows, and then came to the jungle — very different from the open woods of Irazu. The slopes are steep and muddy, the trees enormous and the trail leads through quagmire pools in the midst of gnarled roots. Our horses had great difficulty, and now and again fell and had to be unsaddled and helped to their feet. We passed a *potrera*, or high mountain meadow, which appeared to be the bottom of an old subsidiary crater. Here we left the horses, and on foot climbed to the edge of the great crater. On our arrival it was full of clouds and we could see nothing, so we proceeded higher to a small crater, the slopes of which are wooded, enclosing a cold, clear pond, and on the sand beach we ate luncheon. Then we returned to the great crater and had the good fortune to find it clear. (Fig. 5.) Far below was a pool half a mile in diameter, bordered by bare ash slopes deeply trenched by the heavy rainfall, and scoured by recent eruptions. The pool is of pearl-gray water, continuously boiling at one point. It is like a geyser, and different travelers going there have found it in very various stages of activity. On the occasion of our visit a small dome of water was boiling up at one place, and jets of steam purled away from the surface at many places. At other times it has been known to send up columns high in the air, and on the 25th of January, 1910, it threw out the water and ejected pumice and ash to a great height, some of the ash falling in San José, twenty miles away. Although the volcano still shows this moderate activity, there is no

record in recent years of very tremendous eruptions at this elevation above the sea in Costa Rica.

The bombs of pumice-stone thrown out in the eruption of the 25th of January were of great interest to us in that they had punched deep holes in the soft ground at the edge of the crater. One of these we unearthed from a depth of $3\frac{1}{2}$ ft. and found it to be 16 in. in diameter. (Fig. 6.) It was porous, dark-gray rock, which when broken open showed columnar jointing inward from the outer surface of the bomb.

It is possible that the movements on the great volcanic fissure above which all of these volcanoes are built gave rise to the eruption of January 25, and to that extent this eruption was prophetic of the Cartagò earthquake. Poas and the surrounding country were not affected by the earthquake of May 4 very strongly.

Summarizing the geological data available for the earthquake of May 4, it may be said that the shock was an intense epifocal one, centering somewhere between the cities of Cartago and Paraiso and occasioned by some deep subterranean movement which is not shown by any displacement on the surface. The intensity in Cartago was about No. 9 of the Rossi-Forel scale and the great amount of damage was due to very weak adobe construction. The diminution of strong motion radially outward from Cartago was remarkably rapid. The earthquake may have been related to the chain of volcanoes, but probably indirectly so, as there is no evidence that volcanic explosion under ground or above ground accompanied the shock. The shock was probably occasioned by the slip of a great block of the earth's crust adjoining the west northwest fissure which doubtless was the feeding vent for the line of Costa Rican volcanoes. Cartago is near the southern end of this vent.

It is not unusual for earthquakes and volcanic eruptions to show sympathy in such a region. A marked case of such sympathy was presented by the eruption of Santa Maria in Guatemala, October 24, 1902, following upon a great earthquake in the town of Quetzaltenango which happened the preceding spring. We visited Guatemala after leaving Costa Rica, and traversed the volcano chain of which Santa Maria forms one of the peaks, by way of the railroad which connects Guatemala City with the Pacific Ocean. The southwestern side of the republic of Guatemala is structurally from the Pacific northward a symmetrical succession of well-marked zones. On the Pacific shore there is a broad coastal plain which is an up-raised sea-

bottom. Next comes a mountain wall capped by high volcanoes. (Fig. 7.) The volcanoes have been built by the piling up of ashes and lavas along a great fracture lying at the inner edge of the ocean-laid sediments. Going on northward, next comes an irregular series of high plateaus and rugged mountains consisting of ancient rocks of various kinds. These continue to the north and east until we reach the Atlantic, interrupted only by the drainage basins and occasional lakes. The principal cities are on the high plateaus north of the chain of volcanoes. The eastern metropolis is Guatemala City, the western was Quetzaltenango. Antigua lying at the foot of the symmetrical volcanic cone Agua — the Fujiyama of Guatemala — was the old capital of the country, but in 1773 it was ruined by an earthquake. The authorities ordered a removal of the capital to a plain a little farther away from the volcano line, and here Guatemala City was built. Since that time, the new capital has been fortunate in escaping great earthquakes, but Quetzaltenango in 1902 shared the fate of the ancient Antigua. Throughout the summer of that year, after the Quetzaltenango earthquake, there were shakings and rumblings throughout western Guatemala which kept the people of the coffee plantations in a state of anxiety and expectation. Their fears were justified. Santa Maria, just south of Quetzaltenango, was one of the higher volcanoes of the chain (12 363 ft.), and was supposed to be extinct, but on the 24th of October a steam eruption began in a gorge on the Pacific flank of this cone, which continued for three days, blew a great chasm into the side of the mountain (Fig. 7), and so filled the air with rocks and sand and dust that hundreds of square miles to the west of the volcano were in complete darkness for fifty hours. Hundreds of coffee plantations were ruined to the value of many hundreds of thousands of dollars, and 400 or 500 native plantation workers were killed, mostly Indians. The slopes on Santa Maria and the neighboring mountains were covered with bombs and sand, so that in the photographs taken immediately after the eruption the landscape appears as though it were buried in new fallen snow. (Fig. 8.) There was no flowing lava, and the motive power of the eruption appears to have been chiefly superheated steam which escaped from a hole in the side of the mountain like a jet from a freight engine. This eruption was followed by one or two more sharp earthquakes early in 1903, and thereafter the country quieted down, the eruption apparently acting as a safety valve to release the accumulated stress. As this volcano, Santa Maria,

is one of a chain of high volcanoes from thirty to fifty miles from the coast and rising to heights of from 5 000 to 13 000 ft., it cannot be said that the elevation of a volcano and its removal from the shore line necessarily guarantee its extinction. It is clear from cases of this sort that volcanic eruption and earthquake phenomena are closely related.

In conclusion, I would urge the importance of linking engineering science with dynamical geology in investigation of the earth's crust and its motions. The scientific world has had its interest awakened in seismology and kindred sciences through a succession of frightful disasters of this past decade. Geology, or better *geonomy*, the science of earth law, can show what places are dangerous, what directions earthquake waves habitually follow in those places, what the average earthquake interval is for different places which are known to be centers of disturbance, and what is the probable geological cause of existing stresses in the earth. Engineering science can take advantage of this information, and then construct houses in such places, after the fashion of ships, designed to be buffeted by the earth waves whenever the earth storms take place. We need more precision in our geological work, and the engineer can help us to secure it. We need observatories all over the globe equipped with instruments for recording earth processes. An institution like the United States Weather Bureau, or the Smithsonian, or the Carnegie Institution of Washington, can take the lead in equipping world-wide stations, and this will be done if a sufficient encouragement is given to the work by business men. It was through the sympathy and interest of business men that this expedition to Costa Rica was undertaken, and we are grateful to them for the opportunity, and to you engineers for the interest which you show in our report.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1911, for publication in a subsequent number of the JOURNAL.]

EARTHQUAKE EFFECTS ON STRUCTURES AT CARTAGO, COSTA RICA.

By Charles M. Spofford, Member of the Boston Society of Civil Engineers.

[Read before the Society, October 19, 1910.]

General Description.

The city of Cartago lies in the central portion of Costa Rica, midway between the Atlantic and Pacific oceans and two or three miles east of the continental divide. Its distance from either coast is about ninety miles and it is in direct communication with the important harbor of Port Limon on the Atlantic coast, by the Northern Railway of Costa Rica, a line controlled by the United Fruit Company of Boston, through whose courtesy Professor Jaggar and myself were able to visit the city.

Its elevation above the sea level is 4 700 ft., and although it lies but 10 degrees above the equator, its climate is cool and bracing and it is comparatively free from tropical diseases. It was founded by the Spanish many centuries ago, and has been a place of some importance for a long time. One reads that as long ago as 1710 a Spanish expedition was founded here for the purpose of exploring the gold mines of Panama.

Its population before the earthquake consisted of from 8 000 to 10 000 people, the greater part of whom were said to be comparatively well-to-do. It had many schools, and was a picturesque, quaint town, patronized to a considerable extent by tourists, and in recent years by Americans from the Canal Zone, who used it as a ready means of escape from the humidity and enervating climate of the Isthmus.

The Northern Railway furnishes an object lesson to engineers of the troubles incident to railroading in the valley of a mountainous and tropical stream. Floods and landslides during the rainy season are of frequent occurrence. Scarcely a week passes without trouble of some sort. Within the last two years it has been necessary to spend a large sum in repairs incident to these natural catastrophes. For a considerable period during this time it was impossible for trains to operate between Port Limon and Cartago, it being necessary for a month

or so to carry passengers and freight across one of the valleys in baskets traveling on an overhead cable. The great number of bridges that were destroyed in this period illustrates the strength of these natural forces. The railroad officials state that one steel pin bridge of 275 ft. span was washed away, and not a trace of it found.

The fact that Cartago is located at a point where earthquakes and volcanic disturbances have always been of frequent occurrence, and that it was ruined no longer ago than 1842 by a severe shock, would lead one to suppose that its buildings, or at least its more important ones, would have illustrated in their construction a serious attempt to provide a reasonable degree of security against a similar disaster. One would at least expect such to have been the case in a building like the Carnegie Peace Court, destined to be widely known for its unique purpose, and constructed at a time when the San Francisco, Valparaiso and Kingston earthquakes must have been fresh in the minds of its architects.

As a matter of fact, however, the Cartago buildings, even the best of them, showed in their construction but the most elementary knowledge of the essentials of earthquake-resisting structures. It is true that there were no high buildings, one-story structures being the rule; but that tensile strength of the material, rigid connection of beams and rafters to walls, and of walls to each other, and stability of foundations were of greater importance than low height had apparently not been appreciated by the Cartago builders. They had profited but little from their own experience or from that of others.

In many cases the poorer buildings of the city offered a resistance to the shock but little greater than a child's house of blocks; and with their heavy tile roofs proved veritable death traps to inhabitants as well as to passers-by. The more important buildings such as churches, schools and hospitals, showed but little greater strength and furnished no greater security for human life. The Carnegie Peace Court, the latest public building, was entirely inadequate to withstand a shock of even moderate intensity.

In San José, the capital and largest city of Costa Rica, and but 12 miles distant, more wisdom has been displayed, although that city has never had a destructive shock. One sees there some buildings, such as the so-called iron building, which would probably successfully resist any earthquake shock except one causing actual fissure in the ground under the building.

Not a building in Cartago represented first-class modern construction. In consequence, no direct evidence can be obtained from this disaster upon the resistance to vibration offered by reinforced concrete and steel-frame buildings, although circumstantial evidence upon the resistance of such buildings is abundant. The lesson to be learned from this disaster is rather the dangerous character of the ordinary construction of Central American countries and the relatively greater strength of buildings in which some attention is paid to tying together the different portions of the structure.

The complete ruin of the city, combined with the lack of precise information of its condition before the earthquake, made it impracticable in the time available to collect statistical information as to the relative resistance of the different types of buildings. In fact, it would have been of little advantage to have done this, since a casual examination of the ruins showed clearly the relative merits of the different kinds of construction.

The ordinary forms of construction employed in the city may be divided into four different classes, which, arranged in the order of their frequency, are as follows:

Adobe.

Brick and stone masonry.

Bahareque.

Wooden frame buildings.

If the above arrangement were to be reversed, it would show the relative resistance of the different types to the shock, — a striking commentary upon the wisdom of their builders and owners! Nearly all of these buildings were roofed with heavy red Spanish tiles, which, while offering protection against the sun and rain and adding a touch of picturesque coloring to the city, formed a deadly menace in case of earthquake and were doubtless responsible for a very considerable proportion of the deaths on May 4.

Of these different forms of construction two are unknown in New England, — the adobe and the *bahareque.* The former, however, is commonly used in certain portions of the United States and is doubtless familiar to many of you. It consists merely of sun-dried mud and bricks. To obtain the best bricks, straw should be mixed with the mud, but in much of the Cartago adobe the straw was omitted. As heavy tile roofs cannot be supported by walls of this weak material, wooden uprights are used to support the roof beams or rafters, these uprights being nothing but rough posts inserted a short distance into the ground.

The walls of these adobe buildings are sometimes several feet thick.

Bahareque is the name given to a type of building consisting of a crude wooden framework the uprights of which are held together by horizontal ribs of native cane placed several inches apart. The walls of such buildings are formed, in the case of plain *bahareque*, of a plaster of adobe mud; but in the *bahareque de ladrillo*, bricks are used.

The better type of the plain *bahareque* buildings is constructed by driving into the ground at intervals of about 3 ft. posts of a very hard and long-lived wood, called *guachipelín*, which is commonly reported to have a life of one hundred years. Upon these, posts of an inferior wood are erected, the two sets of posts being thoroughly spliced above the ground level. These

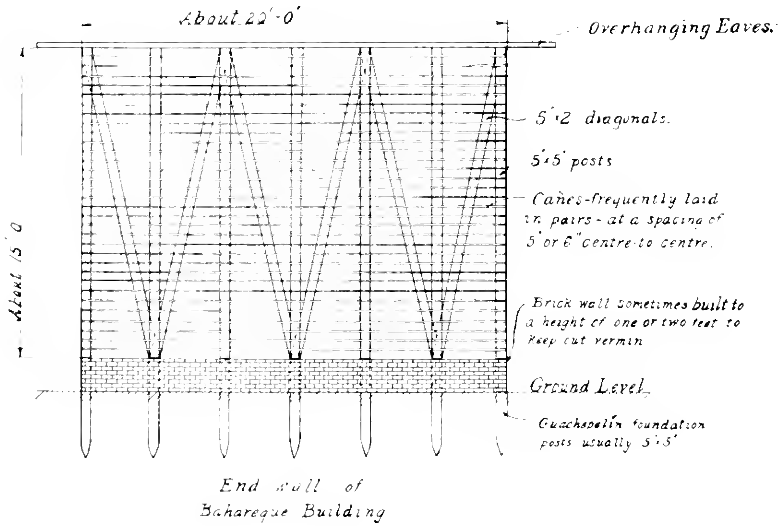


FIG. 3.

latter posts are braced by diagonals, thus forming the framework of the building itself. Upon both the inside and outside of this framework are nailed strips of one of the native canes, laid horizontally at intervals of 6 in. or thereabouts. These strips extend completely around the building, holding the verticals firmly together and forming a sort of basketwork frame or wattle. The mud to form the walls is then pressed by hand between and around the canes. Fig. 3 illustrates the framework of such a building.

The *bahareque* and adobe buildings are plastered inside and outside, and with their red tile roofs present a pleasing appearance, which the description of their mode of construction would hardly indicate. They are cheap, rapid in construction, can be built without skilled labor and form the homes not only of the poorer classes, but also of many of the well-to-do.

The construction of the ordinary masonry and wooden-frame buildings requires no general description, and whatever special description is required will be given later in the account of the behavior of the individual buildings.

The fact that there were so few wooden frame buildings in the city requires a few words of comment. One would think that in a country so sparsely populated as Costa Rica, with many sections covered with thick forests, buildings of this sort would be as common as in those portions of the United States where timber has always been abundant. That this is not so is doubtless partly due to the influence of Spanish architecture, which would naturally be imitated in those of her colonies where natural conditions would permit, and would in consequence result in the choice either of masonry itself or of some inexpensive imitation in non-combustible material, such as adobe. Then, too, the perishable quality of some of the timber when exposed to the trying conditions of the rainy season, and the ravages of the many tropical insects, would doubtless exert a strong influence against the use of the better woods, which really exist in considerable numbers and are said to be of excellent quality. Another serious difficulty, especially in recent times, is the inaccessibility of much of the timber. Roads are almost unknown outside the towns. The settled districts lie along the railroad, and communication between them is principally by rail. To go into the country one must travel by horseback over the poorest sort of trails, which in the rainy season are deep in mud and in the dry season in dust. In our own New England woods the snow and ice of the winter season simplify lumbering operations immensely. In Costa Rica, on the other hand, frost is unknown even in the high mountains at an altitude of from 10 000 to 12 000 ft., and as much of the good timber lies remote from the towns and railroads, it is not easily accessible. It would seem to the writer that the construction of good roads is an absolute necessity for the proper development of the natural resources of this fertile country.

A detailed description of the effect of the shock will now be given.

Foundations.

It has been noted in Japan, as well as in the California earthquake of 1906, that the character of the foundations seems to exert a marked influence on the resistance to shock of different buildings, it being generally the case that buildings founded upon alluvial soil or upon made land are damaged much more severely than those built upon a more solid foundation. The following quotation from an article by Frank Soulé upon the San Francisco earthquake, published in Bulletin No. 324, United States Geological Survey, states the conclusion reached by him from the study of this earthquake: "The destruction wrought by the earthquake amounted to little or nothing in well-built structures resting upon solid rock; and, all other things being equal, increased in proportion to the depth and incoherent quality of the foundation soil."

In Cartago the conditions throughout the city are apparently uniform in this respect. The soil consists of several feet of sand and gravel overlying volcanic rock, the buildings are generally entirely above ground and their foundations are of the simplest character and design and show no attempt to secure special rigidity. In view of the general uniformity of the soil and building foundations throughout the city, no evidence could be obtained to confirm or disprove the general truth of Mr. Soulé's conclusions.

Water Pipes and Sewers.

The effect of the earthquake upon the water pipes and sewers in Cartago was much less marked than in San Francisco. Cartago has a water supply which is considered in that country as being very good and wholesome. The supply pipes are of cast iron, and the water supply was not put entirely out of service by the earthquake. A certain portion of the city was without water for two or three days on account of leaky joints; in another portion the water pressure was reduced; and in still another section no effect was noted. Owing to the non-combustible character of the buildings, no fire followed the earthquake; hence it would have made but little difference had the water pipes been ruptured, as in California; but that this did not occur indicates that the effect of an earthquake such as this upon cast-iron pipes is not necessarily disastrous.

So far as the sewer system is concerned, there seemed to be no evidence of special trouble; and a portion of the system was in use at the time of our visit.

FIG. 18. TYPICAL BRICK BUILDING.

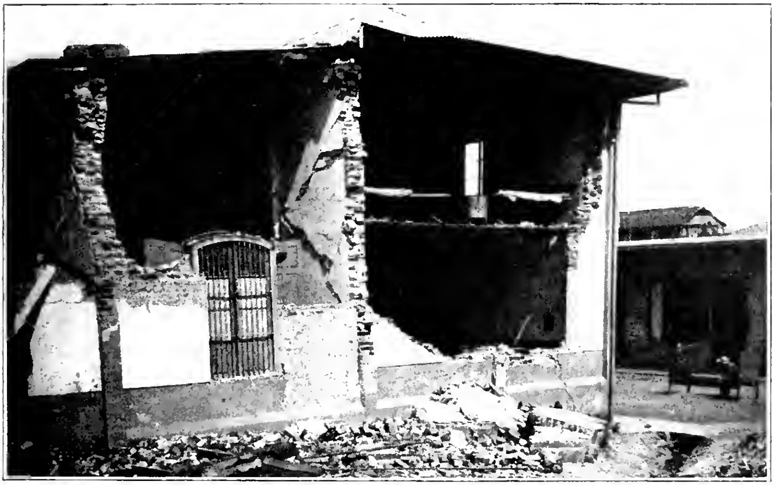


FIG. 19. TYPICAL BRICK BUILDING.

FIG. 38. SMALL BRIDGE NEAR CARTAGO.

FIG. 4. RUINS. ADOBE BUILDINGS.

Street Pavements, Railroad Tracks, Electric Wire Poles, Chimneys.

Such street pavements as existed were of cobble, the blocks being quite large and the gutters in the center of the road. In some cases the sidewalks were of stone blocks laid with mortar, such as the sidewalks adjoining the Peace Court. In no case did these show any evidence of disturbance. This is also true of the cement platforms of the railway stations; these latter were actually cracked, but there is no evidence that these cracks were other than ordinary expansion cracks.

According to the railroad officials, their tracks were not affected by the shock except where injured by falling débris.

The electric wire poles were generally old iron rails or four-segment Phœnix columns firmly embedded in concrete at the base, and these also showed but slight signs of disturbance. I personally noticed but one of these that had been overthrown, and this was perhaps caused by a blow from a falling wall.

There were apparently few if any brick chimneys in the city. The climate requires no heating plants, and the kitchens are usually in small separate buildings, an iron smokepipe furnishing the only chimney necessary.

In view of the general destruction, it may be safely said that no ordinary brick chimney would have resisted this earthquake, and it is probable that such chimneys would not long endure the minor shocks so prevalent in this region.

There is in San José one tall brick stack, but this is braced longitudinally with iron bands and has iron hoops and guy rods. The care used to make this secure shows clearly that its builders were very much alive to the dangerous character of the ordinary brick stack in an earthquake country.

Buildings.

The destruction of these will be described with reference to the material of which they were built, as no other form of classification is possible.

Adobe. — These buildings were very generally destroyed, the mud walls disintegrating under the shock and the heavy roofs falling. The fact that this material has no resistance to tension makes it practically worthless to resist severe sidewise vibration and the resulting diagonal tension accompanying the shearing forces. Moreover, its crushing strength and elasticity

are so low that it can offer little or no resistance to the sudden upward blow of an earth wave. It would seem to the writer that the strength of buildings of this material depends but little upon the thickness of the walls, that is, assuming that the walls be made of reasonable thickness and be not merely mounds of earth. The additional strength, at slightly greater cost, of the *bahareque* construction is so marked as to make it far superior for cheap buildings; and the use of plain adobe in earthquake countries should be forbidden by law, or if allowed, the roof should be of the lightest construction and its supporting beams or rafters rigidly connected to wooden uprights firmly fixed in the ground. It should be noted that nearly if not quite all of the adobe buildings were but one story high. Fig. 4 shows a typical adobe ruin.

Brick and Stone Masonry. — These buildings are grouped together, since little difference was to be noted in their resistance to the shock. The brick buildings were for the greater part, if not entirely, of native bricks, laid with mortar formed from lime of the country. The stone masonry was generally a rubble laid with the native lime mortar. Occasionally, however, a sort of lime concrete was used; this was made by filling a mold with lime mortar and then throwing in stones. The only important building made of first class dressed stone was the parochial church, which will be described later. There was no indication that Portland cement mortar had been used in any of the buildings. The fact that the cost of Portland cement delivered in Cartago is very high has prevented its introduction hitherto to any appreciable extent.

Nearly all of these buildings were more than one story high, and this extra height doubtless contributed to some extent to their general destruction. Both brick and stone masonry were generally poor. In much of the former there was little adhesion between bricks and mortar, the latter frequently scaling away from the bricks and leaving a clean surface. The rubble lime mortar was no better than one would expect.

Perhaps the most striking example of the destruction which these buildings underwent is that of the Carmen Church, shown by Figs. 5 and 6. This building was formed of the lime concrete previously described. The tower, which is shown as fallen across the railroad tracks, was 17 ft. square, and stood in the southwest corner of the church. Its fall was nearly due south and was the only incident of the earthquake which seriously interrupted railroad traffic. In this case the thickness of the

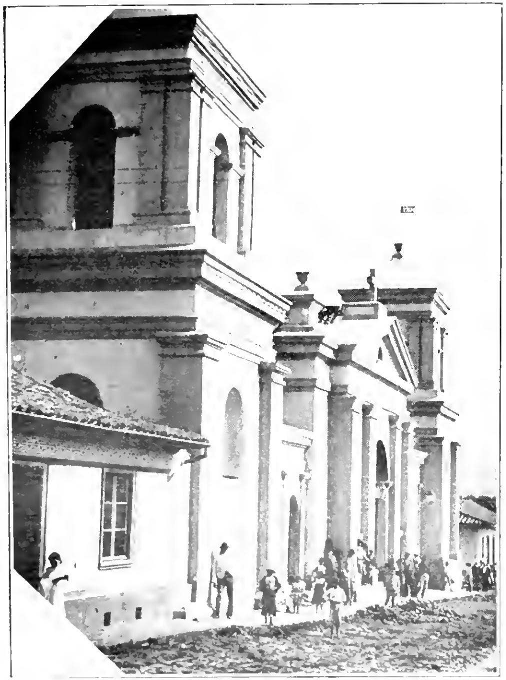


Fig. 5. Carmen Church.

Fig. 6. Carmen Church.

FIG. 7. LOS ANGELES CHURCH.

FIG. 9. WEST END OF LOS ANGELES CHURCH.

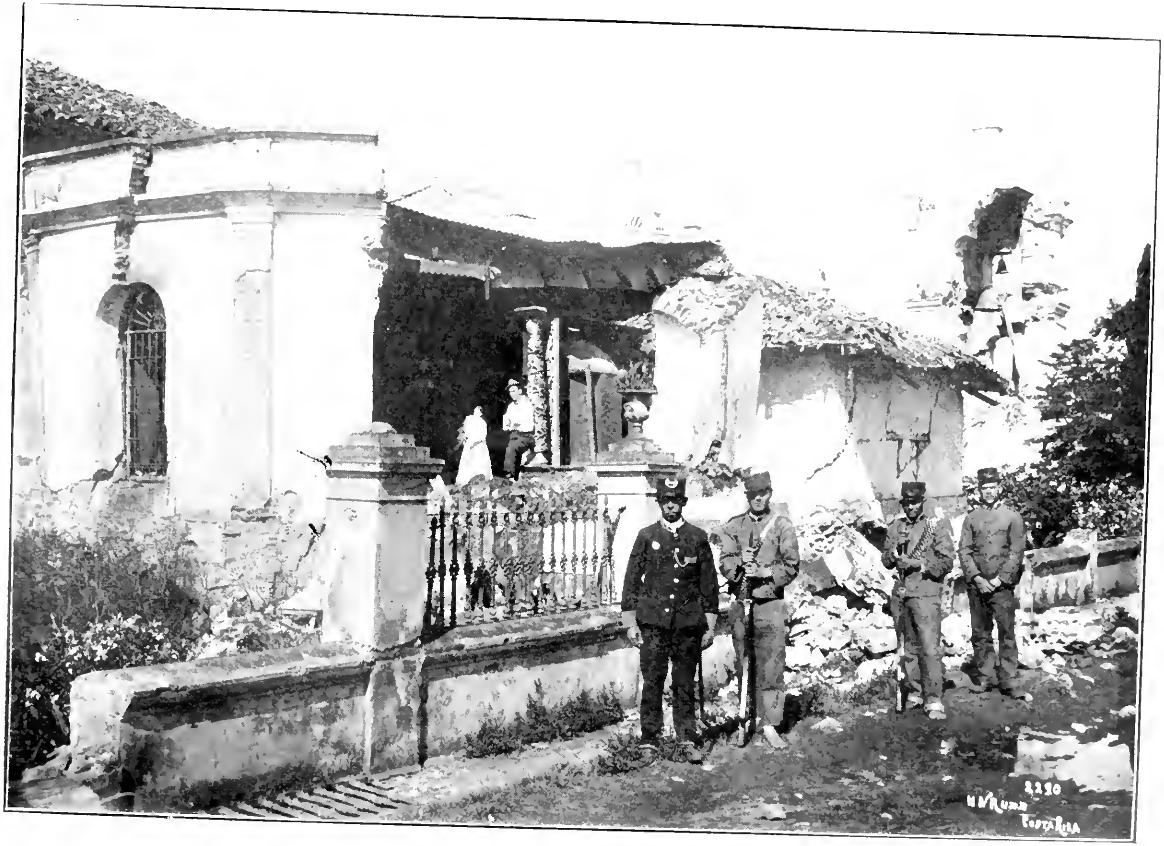


FIG. 8. NORTH SIDE OF LOS ANGELES CHURCH.

Fig. 10. San Francisco Church.

Fig. 11. West End of San Francisco Church.

Fig. 12. East End of San Francisco Church.

FIG. 13. PAROCHIAL CHURCH.

FIG. 14. PAROCHIAL CHURCH, EJECTION OF STONES.

FIG. 17. THE ROUND HOUSE.

masonry and the low height of the tower were insufficient to prevent failure.

Another badly ruined masonry building, the Church of Los Angeles, is shown by Figs. 7, 8 and 9. Fig. 7 shows the church before the shock; Fig. 8, the north wall and the badly damaged northeast corner of the tower; Fig. 9 is the west end of the church and shows the transverse shearing cracks. Cracks of this sort occurred with considerable frequency and were generally located not far above the ground level. In this building the upper part of the tower moved a considerable distance to the south.

Another striking example of failure of the lime rubble is afforded by the San Francisco Church shown in Figs. 10, 11 and 12. This church, like the others, faced west. Here again horizontal cracks are noticeable in the front of the building. The view of the east end, shown by Fig. 12, indicates clearly the very incoherent character of the lime rubble.

While the churches and other stone masonry buildings were generally of this rubble construction, which offered little resistance to shock, there was one church in process of construction, the parochial church previously mentioned, which was being built of cut stone masonry laid with a weak lime mortar. This building stood on the site of a church which had been totally destroyed in 1842. The foundations of the new church up to the water table are said to have been built in 1868, and the reconstruction had recently been begun again, the walls being nearly finished on May 4. This church is shown by Figs. 13 and 14. It is evident from the photographs that this buildings resisted the shock much better than rubble masonry structures, but its damage is so great that partial reconstruction will at least be necessary. Had this been laid with Portland cement mortar instead of the very poor lime mortar used, and had the roof been in position and securely fastened to the walls, it would doubtless have offered a much greater resistance to the shock.

Fig. 14 shows in detail a very noticeable feature — the actual throwing out of some of the stones from the course just above the water table of the north and south walls. This was evidently caused by rocking of the walls.

The partial destruction of the arches was more noticeable in the arches of the north and south walls than in those in the east and west walls.

Brick buildings fared little if any better than those of stone. Perhaps the example of this most interesting to us in Boston is

that of the brick dwelling house occupied by the Guatemalan representative to the Peace Court, whose wife and child were killed in the ruins. The terrible destruction of the house is shown by Figs. 15 and 16. These photographs indicate rather forcibly what might happen in Boston in the case of a similar shock.

Fig. 17 shows the failure of the wall of the railroad roundhouse. This wall originally had three arches which were cracked somewhat by the earthquake of April 13, and had been braced. The bearing of this wall was south fifty degrees west. The rear and side walls were badly cracked, as shown by the photograph. Attention should be called to the great thickness of these walls. The mortar used in the building was apparently of fairly good quality. The turntable in the foreground was not disturbed, railroad employees stating hat there had been no difficulty in operating it immediately after the earthquake.

Figs. 18 and 19 show other badly wrecked brick buildings and require no special explanation.

The Carnegie Peace Court, the most widely known building in the city, was also of brick, with 5-in. vertical *I*-beams embedded in the walls and serving as anchorages for the steel roof trusses, the latter being supported upon the outer walls and upon cast-iron columns in the interior. The building was approximately 120 ft. square and 30 ft. high and was of the patio type with an interior courtyard about 70 ft. by 70 ft. It was designed and constructed under the supervision of a San José architect. All the steel was of the lightest sections and had little or no stiffness. The vertical *I*-beams previously mentioned were tied to the trusses by hoops of thin iron, making a connection incapable of resisting distortion. It is evident that under the influence of vibrations such as those set up by the earthquake this skimpy steel work would be of little or no assistance in holding up the walls. The light *I*-beams, which were spliced by a few bolts at the center, would be bent backwards and forwards under the influence of the swaying action of the roof and serve as big levers to push the walls over.

Figs. 20 and 21 show the building before and after the shock. Fig. 22 shows one of the *I*-beam verticals with its weak splice. Fig. 23 shows the ruin of one end in detail, with a badly bent *I*-beam in the foreground and the statue of Peace lying on the ground. Fig. 24 shows the failure of the wall surrounding the building. The gate-posts shown in these views were of brick covered with stucco and reinforced by an iron rod which was

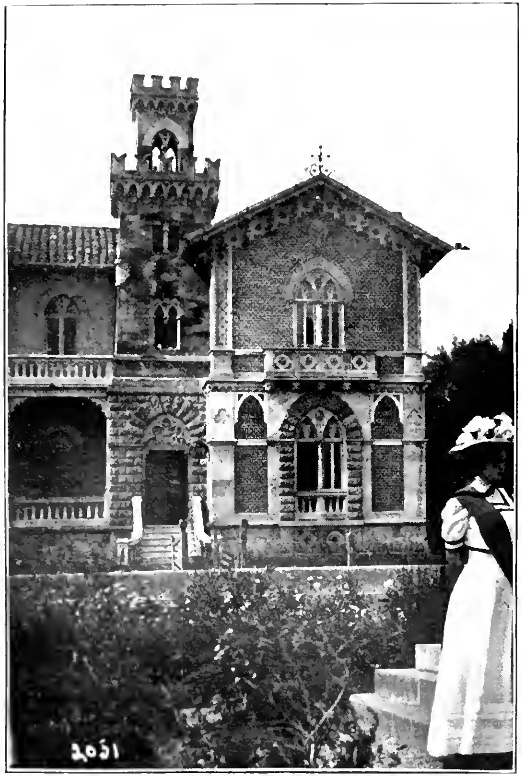


FIG. 15. SENOR TROYO'S HOUSE.

FIG. 16. SENOR TROYO'S HOUSE.

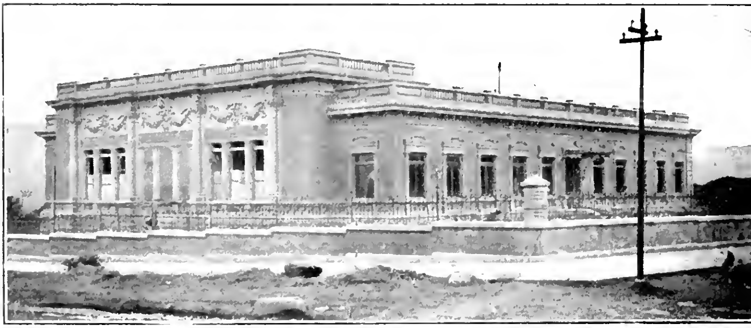


FIG. 20. PEACE COURT.

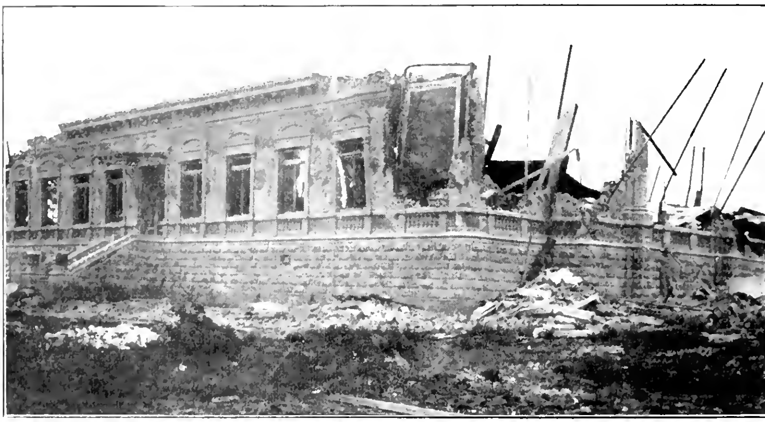


FIG. 21. PEACE COURT.

FIG. 23. ONE END OF PEACE COURT WITH FALLEN STATUE OF PEACE.

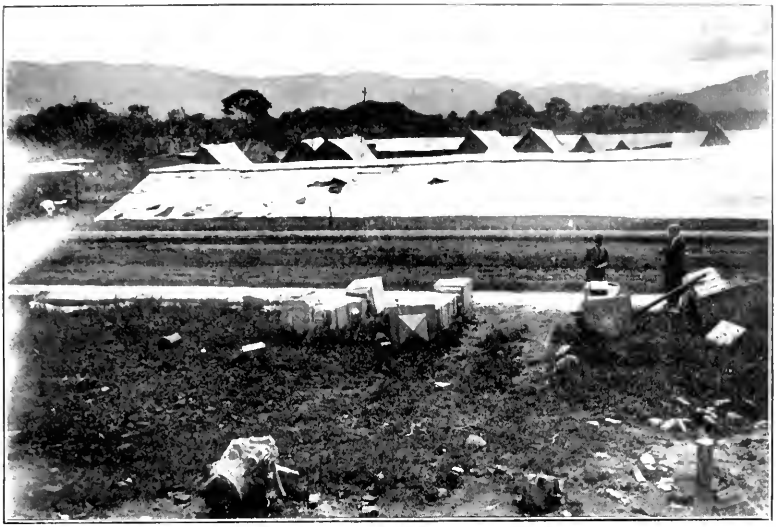


Fig. 24. Failure of Wall Surrounding Peace Court.

Fig. 25. Short Projection of Reinforcing Rod into Foundation, Peace Court.

FIG. 26. BAHAREQUE AND BAHAREQUE DE LADRILLO CONTRASTED.

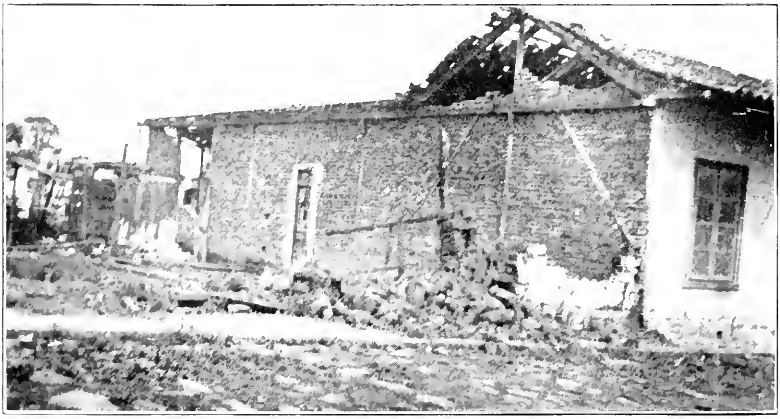


FIG. 27. HOUSE WITH DIAGONAL BRACING.

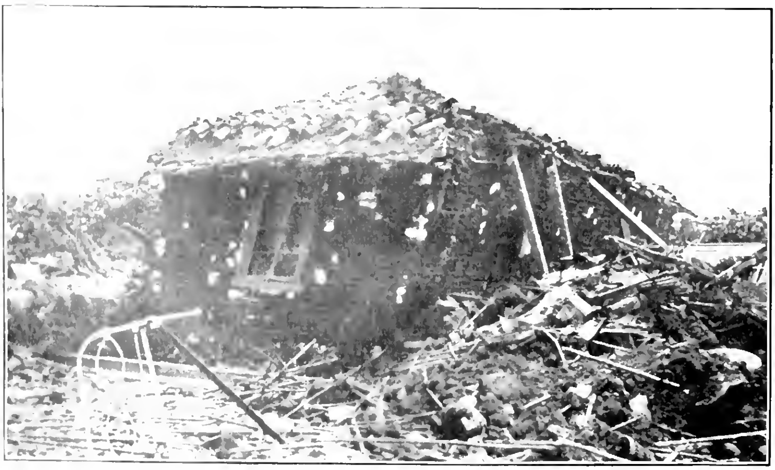


FIG. 28. LISTED BAHAREQUE BUILDING

embedded a short distance in the foundation. The projection of this rod is shown by Fig. 25, and one can easily imagine its influence in keeping the post upright.

I think it may be safely said that the design of this building was such as to make it peculiarly subject to destruction in a severe earthquake. It should be added, however, that the builders did not use one of the heavy tile roofs which contributed so greatly to the death roll throughout the city.

Bahareque and Bahareque de ladrillo. — There was a considerable number of these buildings in the city, but none of them was either large or high. These buildings, with their wooden frames bound together by frequent bands of cane, are perhaps as nearly proof against total destruction as any form of inexpensive non-combustible building. This applies particularly to the plain *bahareque* structures, the bricks in the *bahareque de ladrillo* buildings being occasionally shaken loose. Fig. 26 shows both types, the left-hand one being of plain *bahareque*. It will be observed that while the bricks in one panel of the *ladrillo* building are gone, windows broken, etc., there is no evidence of damage to the other structure. The heavy roof tiles have been removed from the plain *bahareque* building since the earthquake and replaced by corrugated iron.

Fig. 27 shows a *bahareque de ladrillo* building with diagonal bracing, which should always be used, but is sometimes omitted.

Fig. 28 shows the listing that may take place when diagonals are omitted. The longitudinal axis of this house bears north five degrees west, and the building is listed to the east. Had it been braced diagonally, it is probable that this listing would not have occurred. This house is said to be at least one hundred years old.

Wooden-Frame Buildings. — The effect of the earthquake upon these buildings was similar to that observed in other earthquakes. This may well be summed up in the words of Mr. A. L. Himmelwright in his report upon the San Francisco earthquake made to the Roebling Construction Company: "Well-designed and executed wood or 'frame' buildings were but slightly injured by the earthquake. The toppling over of the chimneys and cracks in the plaster finish and cellar walls usually represented the total damage. Sometimes such buildings were shifted a trifle from their original position on the foundations. Even where the foundations were affected, the damage was generally confined to plaster cracks and a slight racking of the frame and was always less than in the ordinary brick or stone walled structures."

In Cartago the two railroad stations of the Northern Railroad of Costa Rica were the only buildings exclusively of wood; and these were both structurally undamaged, although surrounded by ruins. These buildings were both one-story structures. The lower station was damaged to the extent of cracked plastering and the shifting and falling of the roof tiles. The longitudinal axis of this building runs north sixty-three degrees west, and the plastering on end and cross walls was cracked more than that on the longitudinal walls. The cracks in the plaster were, as a rule, near the bottom; and at the time of our visit the entire damage to the interior was being repaired by a negro whitewasher. The frame of this building consisted of 5-in. by 6-in. main uprights, about 3 ft. apart, with 6-in. by 1-in. studding between, spaced about 12 in. The walls and partitions were formed by lathing and plastering. After the earthquake the tile roof was removed and replaced by corrugated iron.

The upper station, for through trains, was of similar construction but had a corrugated iron roof. This building was not injured.

The station at Paraiso, another one-story frame building with corrugated iron roof, was also uninjured.

Figs. 29, 30 and 31 show another example of the resistance of a well-constructed wooden frame. The house illustrated by these views is the Peña house, with a brick lower story and wooden-framed upper story, sheathed with metal laths and lime mortar. The lower story was damaged to a considerable extent, but the upper story was entirely uninjured, no cracks being discoverable even in the wall paper, thus showing the greater resistance of wood over brick. The axis of this building was nearly due east and west.

The wooden framework in this building consisted of studs $4\frac{3}{4}$ in. by $5\frac{1}{2}$ in. spaced about 3 ft. on centers, with the $4\frac{3}{4}$ in. dimension in the plane of the wall. These studs were connected by horizontal battens notched into the $5\frac{1}{2}$ in. side and composed of $1\frac{1}{4}$-in. by $1\frac{3}{4}$-in. strips spaced at about 6 in. in clear and covered with metal lathing and ordinary lime plaster. The partitions were of similar construction, except that the studs were $1\frac{1}{2}$ in. by $1\frac{3}{4}$ in., with the $1\frac{1}{2}$ in. dimension in the plane of the wall. The great solidity of the roof is clearly shown by Fig. 32. The floor plan is not apparent but it is sufficient to say that 6-in. by 6-in. wall plates supported by the wall studs were used and that these were connected by four other 6-in. by 6-in. sticks, two longitudinal and two transverse. The hip rafters were supported

FIG. 22. PEACE COURT, VERTICAL I-BEAM.

FIG. 33. TYPICAL CRACK IN A BRICK WALL.

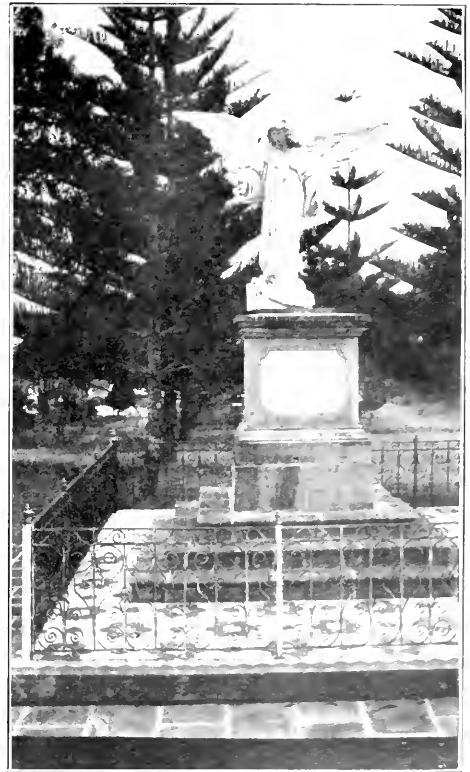


FIG. 37. ANGEL IN CEMETERY, [illegible]

Fig. 29. Pena House, South Wall.
Fig. 30. Pena House.
Fig. 32. Pena House, Roof Framing.

Fig. 31. Pena House, West Wall.

Fig. 36. Water Tank at Railroad Station.

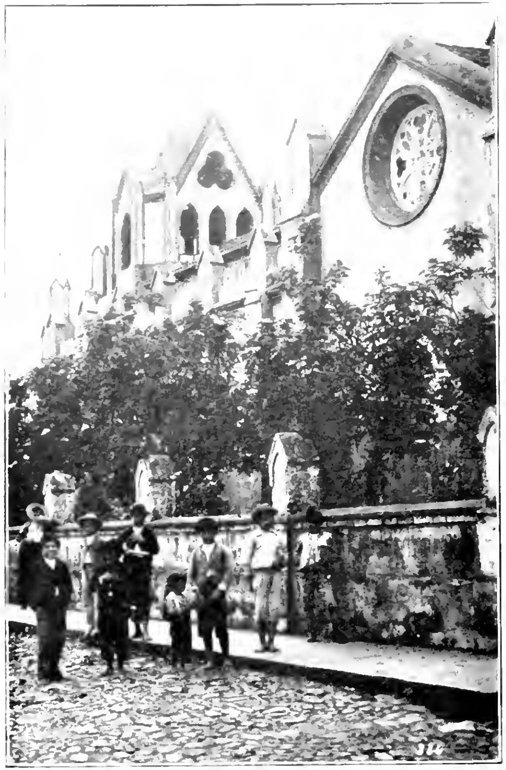


Fig. 34. San Nicolas Church.

Fig. 35. San Nicolas Church.

on a center post carried by this framework. Eight-inch by 2-in. diagonal ties connected the bottoms of these hip rafters with the center, and all jack rafters were supported at intermediate points by inclined struts braced against the 6-in. by 6-in. sticks.

The joints in this framework were all well made, and the immunity to damage of the upper portion of the building, in spite of the racking of the lower section, was very likely due in a large measure to the rigidity of the roof framing, although it is probable that a much lighter framework with a lighter roof covering of corrugated iron or shingles would have been equally effective. This building, however, furnishes a striking proof of the relative value of a wooden framework as compared with brick walls. Had the lower story been of the same construction as the upper, it is safe to say that this house would have escaped with no damage greater than the tipping over of furniture and the possible breaking of windows and of glass.

Special attention should be called to Fig. 33, which illustrates clearly a very common type of crack in brick walls. These diagonal cracks are probably caused by the shearing tendency and the resulting diagonal tension, the fact that there are two cracks at right angles to each other being due to the backward and forward swaying of the building.

Another good example of the relative resistance of brickwork and wooden framing is shown in the residence of Dr. Pirie, also a two-story building. Here the bottom story was composed of lime concrete; the upper walls and some of the partitions were of brick, the remaining partitions being of a construction similar to that described in the Peña house. This house was badly damaged, but by no means ruined. It is noticeable, however, that the brick partitions of the upper story were generally destroyed, while the metal lath partitions — except in some cases where they were improperly constructed — remained in good condition.

Figs. 34 and 35 show the Church of San Nicolas, which furnishes another striking example of the superior resistance of timber. Here the heavy masonry tower at the west end is entirely destroyed, while the interior wooden frame is seen to be nearly undamaged.

Miscellaneous Structures.

The effect of the shock upon certain miscellaneous structures is worthy of note. One of these is the iron water tank close to the railroad station. This tank is shown by Fig. 36. The four upper

I-beams which directly support the tank moved a distance of about 6 in. towards the south and approximately 2 in. to the east, choking the supply pipe, but causing no other damage. As will be noticed in the photograph, the wooden fence surrounding this tank was unaffected by the shock, and this was also true of the near-by railroad tracks.

Tombs and monuments in both the cemeteries at Cartago were badly damaged, with the destruction of the burial vaults. The external walls fell, leaving the skeletons of the buried exposed. Fig. 37 illustrates a very common example of earthquake action; the angel which now faces nearly due north originally faced west, the corner which was originally the northwest corner having moved 24 in. to the northeast. The granite pedestal, tile paving and iron fence were entirely undisturbed.

The cemetery at Paraiso was also badly damaged. Here the front wall, which ran nearly due east and west, fell to the south, as did the receiving tomb, which also had an east and west axis. The east wall, running nearly north and south, was broken down for about 50 ft. but was otherwise uninjured. The west wall was damaged but slightly, but the south wall was badly broken.

Fig. 38 shows a small arch bridge near Cartago. This was of cut masonry, well laid in mortar, the bearing of the road being north fifty-seven degrees east. This bridge was entirely undamaged, although buildings nearby were badly wrecked. On the road between Cartago and Paraiso there were also several bridges of a somewhat similar construction. Of these, only one had been damaged. In this case the bridge had been split across transversely at right angles to the channel, the crack extending from the easterly springing line to the bottom of the westerly abutment. This damage was not apparent in crossing the bridge and could only be observed from below. The northerly parapet, however, was also injured, most of it falling into the stream, which flowed in a northerly-southerly direction.

Guatemala and Panama.

After leaving Cartago it seemed worth while to visit the neighboring country of Guatemala, certain sections of which have suffered severely in recent years from both earthquake and volcanic activities. Our purpose in going there was to observe whether special precautions were taken in building construction to prevent earthquake damage. In the capital, Guatemala City,

the buildings are of considerable height and show no signs of earthquake injuries. Our stay in the country was brief and we found it impossible to visit the city of Quezaltenango, which was badly injured some years ago by a severe shock, but careful inquiry convinced us that nothing new was to be learned from studying reconstructed buildings of this ancient city.

From Guatemala we sailed down the Pacific to Panama and spent a few days in the Isthmus. Mr. Rourke's recent interesting and valuable paper before this society is so fresh in your minds that I will not venture to add to it. I do wish to say, however, that I came away tremendously impressed by the efficient organization, the energetic leaders and the great progress which has been made. The sanitation alone of the Isthmus furnishes an object lesson to the world. Coming there as we did from Guatemala City, which goes to the opposite extreme, I was perhaps more forcibly impressed by this phase of the work than had I gone directly from New York. No engineer who can afford the time and money should fail to visit the Isthmus during the coming year, while the work is still at its height, and no American can come away without feeling great pride in the ability of the United States government to carry out such an immense undertaking.

Kingston.

After leaving Panama we went to Kingston, Jamaica. This city, which was ruined several years ago, is now being rebuilt under very stringent building laws, rigidly enforced by the building surveyor, A. E. H. Herschel, Esq. These laws are framed with the idea of preventing the erection of buildings which are not reasonably safe against earthquakes, tornadoes and fires. The following quotation from the Kingston Building Law, as amended in 1907, shows the type of buildings allowed:

"Every building shall be enclosed with walls constructed

"(*A*) Of brick, stone, or cement concrete; or

"(*B*) Of wrought-iron or steel framework, every member of which must be securely, rigidly and durably connected with every contiguous member; the panels between the said frame being filled in with brick, stone or concrete, efficiently secured thereto; or

"(*C*) Of reinforced concrete; or

"(*D*) Of timber framework, every member of which must be securely, rigidly and durably connected with every contiguous member, the framework being filled in with paneling of brick-

work, or concrete, or other fire-resisting material, efficiently secured thereto, and the timber being protected so as to be fire resisting; or

"(*E*) In any of the materials or methods of construction above described in (*A*), (*B*) or (*C*) for the lower story or stories, with upper story or stories of any of the said materials or methods of construction, or of the construction above described in (*D*); or

"(*F*) In the case of domestic buildings outside the building area having a cubical content of not more than 125 000 cu. ft., or not within 50 ft. of any other building, or of the land of any adjoining owner

"(I) Of timber framework, framed as above described, covered externally with wood; or

"(II) In any of the materials or methods of construction described above in (*A*), (*B*), (*C*), (*D*) or (*E*) for the lower story or stories with upper story or stories of timber framework of either of the above descriptions.

* * * * * * * * *

"With a view to securing buildings as much as possible against the lifting effects of wind pressure, every building, and the component parts of such building, shall be tied together by ties acting effectively in a vertical direction; that is to say, all parts of the roof or roofs shall be securely nailed, screwed, spiked or bolted together, as the case may require; the roof or roofs shall be effectively held down to the walls, columns or posts; the walls shall, if of framework, be continuously tied vertically from the uppermost wall plates to the sills, and the sills, columns and posts shall be anchored down to the foundations. The system of tying adopted, and all ties, shall be of a design approved of by the surveyor.

"With a view to securing buildings as much as possible against the racking effects of earthquakes, due to severe horizontal vibrations and oscillations attending them, the horizontal strength and stiffness of the floors and roofs and the vertical strength and stiffness of the partitions or cross walls is to be brought in assistance of the walls, the latter, if outer walls, being tied to the joists, beams or slabs of the floors, and to the framing or the body of the partitions, and, in case of there being cross walls in any building, the floors and the partitions on either side of such cross walls being effectively tied through such cross walls to each other, thus in the first case holding the outer walls against overthrow in position against the edge of the floors and partitions, and in the second case holding the cross walls in position between the opposite floors abutting on them and creating through horizontal ties between the outer walls. The tops of the walls shall be similarly secured by being held in position by holding-down bolts or other ties, connecting the roof system to them. The system of tying adopted, and all ties, shall be of a design approved of by the surveyor."

In addition to stringent building laws, precaution has been taken to secure good concrete by imposing a duty upon cement varying with its quality, the rate for poor cement being so high as to make its importation unprofitable.

As a result of these laws Kingston is rapidly becoming a reinforced concrete city and furnishes an excellent example of the use of this material in building. Not only the public buildings, but the more important private buildings as well, are of concrete, and present a most pleasing appearance.

CONCLUSIONS.

The writer believes that the following conclusions may safely be drawn from the results of this earthquake:

1. That no building constructed entirely of material with low tensile resistance or little elasticity is safe against severe shock. This applies to adobe, ordinary brickwork laid in lime mortar, and lime mortar rubble.

2. That buildings of cut stone masonry laid in lime mortar, even when of low height, are subject to considerable damage by severe shocks, although they may not be entirely destroyed.

3. That in general, elasticity, continuity and lightness of structure are of more importance than thickness of walls or low height.

4. That wooden-frame buildings of moderate height, with walls and partitions formed of metal laths or expanded metal covered with lime plaster, will resist with little or no damage very severe shocks provided no earth fissure occurs. Such buildings should have continuous or thoroughly spliced vertical and horizontal members, which should be well tied together at joints; roof rafters should be securely held at ends by continuous horizontal ties, and floor joists firmly fastened to the vertical members.

5. That a cast-iron water-pipe system will probably suffer from leaky joints, but may not be put entirely out of service unless the shock be accompanied by actual fissure.

6. That projecting balconies and cornices and heavy tile roofs are dangerous in the extreme. The latter should be prohibited by law, and the former used only when constructed in the strongest manner and under rigid inspection.

It is to be regretted that no reinforced concrete or steel-frame buildings existed in the city, and that it is, therefore, impossible to present conclusions concerning their behavior. There

seems little doubt, in view of the experience in San Francisco, that steel-frame buildings properly built and braced would have resisted this earthquake as well as, if not better than, wooden-frame buildings.

What would have happened to reinforced concrete is somewhat problematical. The concrete itself has little tensile resistance, this being furnished entirely by the steel reinforcement. It is evident that unless the walls are reinforced with steel diagonals, cracks may occur due to diagonal tension produced by the horizontal shearing forces. It is the opinion of the writer that reinforced concrete, when properly constructed under rigid supervision by competent engineers, should resist earthquake shock like this without being destroyed, although it might be badly cracked and difficult to repair. Its weight is against it. The experiment at Kingston is an intensely interesting one, and the effects of the next severe earthquake upon its numerous concrete buildings should be carefully studied by all engineers.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1911, for publication in a subsequent number of the JOURNAL.]

ANNUAL ADDRESS.

By W. B. Gregory, President of the Louisiana Engineering Society.

[Read before the Society, January 14, 1911.]

HYDRAULIC ENGINEERING.

Engineering was defined by Tredgold in 1827 as "the art of directing the great sources of power in nature for the use and convenience of man."

Nearly a century has elapsed since this definition was formulated, and although engineering still continues largely to be an art, it has appropriated and applied much that is purely scientific. The modern conception of engineering was stated by F. R. Hutton in 1907 in an address before the American Society of Mechanical Engineers, when he said, "The engineer is he who by science and art so adapts and applies the physical properties of matter and so controls and directs the forces which act through them as to serve the use and convenience of man and to advance his economic and material welfare."

Less than half a century ago the two great divisions of the subject were Military Engineering and Civil Engineering; and these divisions still hold good, while the numerous subdivisions corresponding to special lines of work have somewhat changed the popular conception of the terms. Civil engineers still insist that all engineering not military must be classed under the general head of Civil Engineering. Nevertheless, specialization has resulted in subdivisions, and we have societies of national and even international importance representing Mechanical, Electrical, Mining and Marine Engineering, the Testing of Materials and other lines. Specialists in various subjects have organized sections composed of members who are interested in some particular phase of these larger divisions, and we find a Gas Engine division of the American Society of Mechanical Engineers as an example of the further subdivision that is constantly going on.

The question may well be asked,—Where does Hydraulic Engineering enter into the scheme?

In looking over the papers and discussions that make up the transactions of the great societies, we find that a large number of the most valuable contributions to the subject of hydraulic engineering in this country have been presented to the American Society of Civil Engineers. They are, however, not con-

fined to the publications of that society, for occasionally they appear in the transactions of the American Society of Mechanical Engineers, the American Institute of Electrical Engineers and in the publications of some of the smaller local societies. Our own Louisiana Engineering Society has had some papers of unusual excellence — papers that will be placed among the classics of future libraries on hydraulic engineering. Some of these papers will be briefly referred to later.

The problems confronting the modern hydraulic engineer are many, and while the field of the water-works engineer is quite different from that of the drainage engineer or the irrigation engineer, they have many problems in common. To accomplish the best results in any of these lines requires a knowledge of the principles of mechanical and of electrical engineering as well as those of hydraulics.

In some lines, practice has become fairly well standardized, while in other lines there exists the widest diversity. In each there is plenty of scope for the application of the latest and best discoveries to the solving of the problems that are presented to the engineer.

This is the age of the specialist. Nevertheless, the successful engineer in practice must know the fundamentals of several lines of engineering to wisely decide on the best method of solving a particular problem.

An educated man has been defined as one who knows something about a great many subjects and a great deal about a special subject, and this applies with unusual force to the modern engineer.

Historically the science of hydraulic engineering dates back nearly twenty-two hundred years. About 250 B.C. Archimedes established a few of the principles of hydrostatics, and showed that the weight of a body immersed in water was less than its weight in air by the weight of the water it displaces. Crude pumps of the chain and bucket type were used by the Egyptians at this period and the force pump was invented about 120 B.C.

The Romans displayed great skill in building aqueducts as early as 300 B.C., and later used earthen and lead pipes to convey water to their houses.

Merriman says that "while the Romans knew that water would rise in such a pipe to the same level as in the aqueduct, and that a slope was necessary to cause a flow in the latter, still they had no conception of such a simple quantity as a cubic

foot per minute. Rome was destroyed in the year 475, and even this slight knowledge was lost, and Europe, for a thousand years sunk in barbarism, made no scientific inquiries until the Renaissance period began."

The name of Galileo stands out preëminently at the beginning of the seventeenth century as a scientist who investigated many different fields. His work in astronomy was remarkable. He invented the telescope and he announced a theory of the universe that insures for him a place among the immortals.

Up to the time of Galileo, men were too much given to accepting the work of the ancients without question. The philosophy of Aristotle was unquestioned, and the greatest good wrought by Galileo was in creating doubt as to the ancient order and by putting the questions of science to nature herself to be answered by experiment. However, the popular mind does not readily change its attitude, and we find it recorded that when Galileo announced that Aristotle was wrong in asserting that two bodies of different densities would fall to the earth in periods depending on their densities, and actually demonstrated the truth of his statement by dropping a heavy and a light body from the leaning tower of Pisa, and showed that both struck the earth at the same instant, — still they went away declaring that Aristotle was right and Galileo wrong. Thus the crystallized ideas of the past could not easily be changed although the seed was sown, and from that time forth scientific theories must stand the test of experiment or finally perish with the unfit.

Compare this attitude of mind with that of our day. The last one hundred years, and especially the last seventy-five years, have seen such wonderful discoveries of hitherto unknown forces and their applications to the needs of every-day life that the middle classes of our time enjoy comforts that were unknown to kings a century or two ago. The public mind has been trained to expect new and startling discoveries. The promoter of the Keeley motor had no trouble a few years ago in persuading business men of keen intelligence to aid in the development of a fake machine which was believed to embody a new principle and to be operated by a newly discovered force.

The same attitude of mind may be illustrated by an example nearer home. In this city there has recently been dismantled and sold for junk a wonderful network of gears, balance wheels and water wheels, some of the latter 35 ft. in diameter, which

had been erected to prove that it was possible for an overshot water-wheel to furnish power to pump the water to run itself and at the same time have a surplus of power for other purposes. To build this experimental plant more than fifty thousand dollars were used, and this in spite of the fact that the principal stockholder had been warned at the beginning that the scheme was destined to failure.

Galileo discovered the law of falling bodies, which law is at the foundation of the theory of hydro-mechanics. However, he was not always right, for it is reported by Bernard that Galileo made the mistake, in discussing the flow of water in rivers, of maintaining that in two rivers having the same cross sections and the same fall, the velocity of water would be the same, whatever might be the respective lengths of their channels; also that the windings of a river, unless they formed very sharp angles, caused very little or no retardation of flow.

Galileo declared in 1630 that the laws controlling the motion of the planets in their celestial orbits were better understood in spite of their amazing distances, and presented less difficulty than did the laws of the flow of water in rivers, which took place before his very eyes.

Another curious error of the early philosophers is recorded by Pitot in a paper presented to the French Academy in 1732. He states that he found in all the available works on hydraulics that the velocity of water in a river must be, by the then generally accepted theory, greatest at the bottom and least at the surface. Pitot, by the invention of the tube that bears his name, was able to show that almost the reverse was true, namely, that the slowest velocity was near the bottom and the greatest velocity near the top.

While these blunders seem absurd to engineers of the present day, it must be remembered that they were the natural result of the system of evolving theories from the inner consciousness by processes of pure reasoning when all the factors were not known.

The evolution of the science of hydraulics has been slow largely because theory must be tried out by experiment and thus all the factors entering into a problem finally determined. The science could not make much progress until proper instruments had been invented to make accurate measurements possible. Even after the necessary instruments were available, results of importance must await the genius who could effectively use the instruments and properly interpret the results obtained. Thus the Pitot tube was a scientific toy for more than a hundred

years until D'Arcy and Bazin adapted it to their splendid research work on the flow of water in open channels.

The paper entitled "The Pitot Tube; Its Formula," read by W. M. White before this Society in May, 1900, marked another epoch in the development of this instrument, which in the last ten years has taken a place among the devices for the accurate measurement of the velocity of water.

The development of the science to meet modern conditions has led to the application of the researches of the theorist to the practical problems of everyday life. This is illustrated in the works of Venturi and of Bernouilli, which dealt with the theories of the flow of water in pipes. When applied to a practical device by the modern Herschel, the Venturi meter was invented and one of the most accurate and satisfactory of known methods of measuring water was the result. Engineers throughout the world acknowledge their indebtedness to the careful researches of Francis, of Hamilton Smith, of Fteley and Stearns, and to other American engineers in determining the factors that control the accuracy of weirs.

The work of the United States Army engineers Humphrey and Abbott in studying the problems of the Mississippi River still remains a classic after more than half a century of the greatest progress the world has ever seen in all lines of theoretical and applied science.

The engineers of this section of country and the members of this Society have done their share in the field of hydraulic engineering. The work of our own Major Harrod, who devoted more than twenty-five years of his life to the study of the great river, has resulted in the solving of some of its problems and especially that of removing sand bars and maintaining a navigable channel.

Only last month the members of the Society enjoyed a most excellent paper by Major Frank M. Kerr, chief of the State Board of Engineers, who has devoted many years of his life to controlling the rivers of the state and to perfecting its levee system.

The engineers who have given an abundance of pure water to this city, who have provided a drainage and a sewerage system, — all these improvements the equal of those of any modern city, in fact, models that are being followed by those who would have the latest and best, — are among the members of this Society.

Louisiana has been the pioneer state in modern rice irriga-

tion, and many of the problems involved are as yet unsolved. More water is pumped for the purpose of irrigation in this state than in any other state in the union, in spite of the fact that the climate is humid and the annual rainfall from 48 to 60 in. per annum. Many of the best of the pumping plants have been designed and erected by members of this Society.

But the work of the hydraulic engineer in this section has only been begun. In this state we are to witness the application of the latest researches in hydraulics to the disposing of large volumes of drainage water by pumping. Louisiana is often called the Holland of America. The conditions here and in Holland are similar in some respects, but they differ in the magnitude of the drainage problem. The alluvial lands of Louisiana comprise about one fourth of the area of the state and cover more territory than the whole of the Netherlands. Of the 28-000 000 acres of land in this state only about 3 000 000 acres are in cultivation. Holland has won from the sea since the sixteenth century more than a million of acres of land. The coast marshes of Louisiana amount to nearly five millions of acres. When these rich alluvial lands have been transformed into fruitful farms by means of drainage, this state will become the garden spot of America, and imagination fails to picture the results.

Not only will there be cheap food in abundance for the dense population that is sure to occupy these lands, but because of the favorable conditions of soil and climate the returns from the plantations, the farms and the gardens will assure to agriculture a full measure of success.

Already the work of reclamation has been started. Many of the sugar plantations have lands reclaimed from the swamps, which annually yield bountiful crops because they have been adequately drained.

In a few cases farms are now cultivated that a few years ago were covered with water during the greater part of each year.

There are details of the drainage problem yet to be solved that are of great economic importance. Only a little work has been done in studying the relationship of run-off to rain-fall.

The best dimensions to use for canals that must act as storage reservoirs as well as channels to conduct the water to the pumping plants are as yet unknown. The greater the capacity of canals, the smaller the capacity of the pumping plants may be. The best way to keep these canals free from vegetation and to maintain the proper depth of channel, the most

economical method of draining the fields and the innumerable details that enter into the problem will probably be found to vary somewhat with the soil, the crop raised, the methods of cultivation and with other conditions.

The problem of the pumping plant to remove the excess water — elevating large volumes through a small height, but in the aggregate using thousands of horse-power to accomplish this end — is worthy of careful consideration.

The best type of engine and boiler, or the possibility of electrical transmission from a central power plant in which the prime movers may be internal combustion engines or steam engines, will have to be considered. Finally, all these factors must be combined by the drainage engineer in a way to produce the best result when first cost, interest on investment, depreciation, fuel and labor are all considered. The desired result will not be brought about by the hit-and-miss methods of the rule of thumb mechanic. Or rather, if it is to be wrought out in this way it will be at great sacrifice of effort, time and money. The problem is largely experimental, it is true, but the place to settle many of the points involved is in a well-equipped laboratory of hydraulics and by men who are trained to see the problem as a whole and who combine the theoretical accumulated knowledge of the past with a practical knowledge of present needs and who can call to their assistance the experimental side of hydraulics as it exists in the laboratory and in the field.

To provide such training for their technical students many of the universities of the North, the East and the West, and in a few cases those in the South, have provided liberally for the study of theoretical and experimental hydraulics. Here in the city of New Orleans, in the heart of the territory that is to be transformed through the efforts of the hydraulic engineer, some provision of this character ought to be made.

The College of Technology of Tulane University is rejoicing because the Stanley O. Thomas Hall will soon be added to that college. The new building, however, will not be devoted to the development of hydraulics to any extent, and therefore this great opportunity at our very doors must remain as a challenge until some way is found to raise the necessary funds to make the dream a reality. We, as engineers interested in the future of this section, should do all in our power to make this development a possibility, for in this way we will aid in the economic success of the state in which we live and in which we are all vitally interested.

THE GAS ENGINEER AND THE GAS INDUSTRY.

By R. S. Feurtado, Member of the Civil Engineers' Society of St. Paul.

[To be read before the Society, March 13, 1911.]

One class of engineering which might properly be said to include almost all of the other branches is that of *Gas Engineering*.

To verify this statement, it may be well to state that a gas engineer has to be versed in Civil Engineering, so as to enable him to properly plan the whole plant, and study the nature and bearing qualities of substrata, to decide the proper steps necessary to provide stable foundations for buildings, as well as for gas holder.

He must be able to lay out a proper system of mains in order to maintain a uniform flow of gas in all sections, and to carefully and comprehensively plan the grading of the sizes of mains, so that there will be a proper supply of gas for those living nearest the works as well as for those living in the suburbs, perhaps many miles away.

Unexpected developments call upon him at times to devise ways and means and supervise the laying of mains through quicksand, or across rivers. Take, for instance, the undertaking by the New Orleans Gas Company, whereby a gas main was laid under the waters of the Mississippi River; here a depth of one hundred and twenty feet was found, two hundred and fifty feet from the water's edge. A very interesting article on this subject was read before the Western Gas Association, at its twenty-sixth annual meeting, in Indianapolis, Ind., in 1903, and was prepared by Mr. T. D. Miller.

He must be able to run levels, so that mains may be laid to a correct grade, and properly locate drip pots, valves, etc., also to prepare plans, specifications and estimates, as well as to supervise the work.

The designing of the roofs and coal-handling machinery comes under the department of Bridge Building or Structural Engineering, and the checking over of manufactures, designs and specifications properly comes under that of Mechanical Engineering.

In the operation of the plant he must be possessed of some knowledge of chemistry and lighting.

It is necessary for him to have the ability to determine the results being obtained from the steam boiler and engine in use, and he should therefore be familiar with Steam Engineering.

In many instances, the driving power used for divers purposes around large works is either Gas Engines or Electric Motors, so that he must also be familiar with these.

Heating and ventilating systems for all the buildings must be considered, so that he also embraces these branches.

He must be able to advise the patrons of the company how best to apply, and through what channels results are to be obtained from the gas used.

And last, but not least, he has often to appear before city and village authorities, to secure franchises and adjust difficulties, so that he must also be a "Diplomat."

Having set forth some of the requirements of a gas engineer, let us now consider the history of the gas industry. In so doing, I am quoting from such authorities as Thomas Newbiggin, of England, and William Mooney, of the United States, and I will take this opportunity of thanking certain practical men in the gas industry in this country who have afforded me great assistance by furnishing some of the historical facts contained herein.

Between the years 1792–1798, William Murdock experimented in Redruth, in Cornwall, and other places in England, with different kinds of coals, and in devising apparatus for their distillation, and in 1796, lighting by gas was an accomplished fact. The circumstance that coal would yield an illuminating gas was known long before that time. Natural gas, as it was found to issue from the bowels of the earth, in particular districts where coal deposits existed, had been a subject of frequent observation, and its lighting power was proved by actual trial, but no practical application was made of the knowledge until Murdock set his mind to the study of the subject. A century and a quarter is a long time in the history of an industry, longer than one exactly realizes at a first glance, especially we in these United States who are accustomed to see cities grow up in a decade. The lapse of so many years since the discovery and application of gas lighting confers something of the venerableness of age to the art. This is more obvious when cognizance is taken of the institution of other arts, and the advances which have been made in these, and not less so is the progress of sciences, within that period of time.

Take railways, for example. As compared with these gas lighting is old, for it had a start in life of thirty years before them.

Nay, even the steam engine is no older than the art of gas lighting, and much of its initiation and perfecting were due to the same fertile brain, for Murdock was Watt's right hand man at Soho, and invented the D. Slide Valve, the "Sun Planet" Motion, and the Oscillating Steam Engine.

Like all discoveries, obstacles had to be met in this art before it could be made a commercial success; among which must be numbered the presence of impurities in the crude gas, as well as the proper pipes and conduits through which the gas could be conducted, and in "Newbiggin's Hand Book for Gas Engineers," we find that "Murdock devoted much time and effort in these directions, washing the gas with water, and employing other means to purify it, and using tinned-copper and iron tubes for its distribution."

In 1805 Dr. William Henry, of Manchester, England, first suggested the use of lime as a purifying medium, and so important was the discovery that to-day lime is still being used for this purpose, when it can be purchased at a price to warrant so doing. At this stage of its development, we find that Lebon, in France, Winsor, of London, Samuel Clegg, of Birmingham, Dr. Henry, of Manchester, and others in England, as well as Melville, of Newport, R. I., were working heart, soul and body to remove these and other obstacles.

Samuel Clegg, however, seemed to have been possessed of the most mechanical skill, combined with common sense. In 1805, he began to apply himself to the invention and construction of gas apparatus, among which was the hydraulic main, and the purifier, in which lime was used for purifying the gas. He also invented the "wet gas meter." Clegg had an able assistant in John Malam, who perfected the gas meter, which is conceded to be one of the most ingenious measuring appliances of this or any past age.

Newbiggin, speaking of the early commercial features of the art, says: "The 'Chartered' Vessel, launched by Winsor, and others associated with him, floundered about for a while in a troubled and, at times, a boisterous sea — due, no doubt, to inexperience, but largely also to incompetence of some of those in charge — till, at length, the skillful pilotage of Samuel Clegg, who eventually assumed the command, brought it into smooth waters." It would therefore appear that the claim made by me, that a gas engineer must be an "all-round" man, and also a diplomat, has been fully substantiated by Mr. Clegg's record.

When gas was first proposed for use in England, the idea was laughed at, and Sir Walter Scott, in 1803, writing to a friend said: "There is a mad man proposing to light London with smoke." Upon its successful introduction, it not only became a great curiosity to the public, but the lamplighters, accustomed to oil lamps, looked upon the new illuminant with great suspicion, and perhaps fear, and for a while refused to have anything to do with it.

Having given a brief history of the early gas era, it is now proper to advance step by step, as the industry grew. It has been shown that the discovery of natural gas was the stepping-stone to the discovery and development of the gas industry.

The foregoing brief history applies exclusively to England, and the reader must not for one moment think that in the United States, the "wisemen" were not alert. In "King's Treatise" on "Manufacture of Coal Gas," Vol. I, page 30, we find the following:

"In the United States, gas for illuminating purposes was first manufactured by David Melville, of Newport, Rhode Island. Melville, who seems to have been a man of an ingenious turn, hearing the reports of what was being accomplished in England, gave his attention to the subject, and as early as 1806 had devised an apparatus by which he lighted his house and the street in front with gas of his own manufacture. This apparatus he improved from time to time, until, on March 18, 1813, it was finally patented by him."

"By its use, he also lighted a cotton mill at Watertown, Mass., and the Wenscutt and Arkwright Mills, near Providence R. I., and in 1817 it was employed in the Beaver Tail Lighthouse, this being the first application of gas to lighthouse purposes. It is said that the new mode of illumination was continued in the lighthouse for one year, giving great satisfaction, but owing to the representations of interested persons, who became alarmed at the unexpected success of the experiment, the new light was discontinued at the end of that time."

There appears, however, to be some doubt as to the original place in which gas for illuminating purposes was first made in this country. Newbiggin mentions Melville, of Newport, R. I., U. S. A., and King comes out and declares that David Melville gave his attention to this subject as early as 1806, and that in March, 1813, he obtained a patent, and that in 1817 gas was used in the Beaver Tail Lighthouse. This claim has, however, been contested by certain authorities, and it might be well to say that certain parties in Baltimore were also as alert as Mel-

ville. The following interesting item, published on December 30, 1815, in the *American & Commercial Daily Advertiser* (now, Baltimore *American*), will doubtless be of interest to our readers.

"Gas Lights.

"We learn by the later English papers that Covent Garden Theater, and a number of the streets of London, are now illuminated by gas light. They are represented as being infinitely more brilliant, more innoxious, and vastly more economical than the common lamp light by oil."

"We have been induced to notice this improvement by the curious circumstances that it was first offered by the inventors to the people of Baltimore, about eight or ten years ago (1805 or 1807), but the people of Baltimore then laughed at the idea. Now that it has been carried into effect in London, no doubt our citizens will look upon it in another light."

"An American inventor, it would appear, can have little credit in America until he receives the sanction of the people of London, and then he has a chance of becoming fashionable on this side of the Atlantic."

This pointed newspaper criticism resulted in experiments in the manufacture of gas, and gas lights were exhibited in the following year as an attraction in Peale's Museum, on North Holiday Street. Peale was a man of great discernment, and foresaw, clearly, the marvelous possibilities of gas. He was also a believer in the use of printer's ink, for in the Baltimore *American*, in its issue of June 13, 1816, the following announcement appeared:

"Gas Lights.

"Without Oil, Tallow, Wick or Smoke.

"It is not necessary to invite attention to the gaslights by which my saloon of paintings is now illuminated; those who have seen the ring beset with gems of light are sufficiently disposed to spread their reputation; the purpose of this notice is merely to say that the Museum will be illuminated every evening until the public curiosity shall be satisfied."

The success of Peale's exhibition laid the foundation for the general use of this form of illumination, as the success of the demonstration immediately resulted in the formation of a company for the manufacture of gas in sufficient quantities to light the entire city. It began operation in the year 1821, which marks a new era, for Baltimore was the first city in the United States lighted by gas. Not only have wonderful ad-

vances been made in the methods of manufacturing gas, but its field of usefulness has been so extended by new applications that the purposes for which it is now used may be numbered by the score. The industry has proven to be one of the greatest boons, and so largely does it enter into the everyday life of the people that it has become a necessity the loss of which would be considered a great calamity.

The gas industry to-day comprises the following systems: coal gas, water gas, producer gas and natural gas.

The subject is so broad and is composed of so many elements that space does not permit me to deal with the whole, or even the greater part of it. Inasmuch as coal gas was the first system developed and commercially used, I will limit myself to a description of such a plant, to supply a city of 30 000 inhabitants.

Real Estate. First of all, a plot of land of sufficient size, alongside a river, beach or railroad, whereby transportation facilities will be of the best, must be secured. Then a close survey should be made, and a map prepared, on which should be platted the location of the buildings, holder and railroad track, or dock. In determining the location of buildings, etc., future improvements and extensions must be considered, and the plant so laid out that in adding to its capacity it will be done at the least possible cost. The machinery and apparatus shall be so constructed and connected that additions and alterations can be made without interfering with the operation of the plant.

Buildings. The buildings necessary are:

A. The retort house — coal house.
B. The exhauster house.
C. The purifying house.
D. The meter house.

(*A.*) *The Retort House* must be of ample size to accommodate the number of benches which are to be installed, and must have sufficient room in front as well as in the rear of benches to allow freedom in working.

The building should preferably be of brick construction, with the walls stiffened by pilasters, and the gables finished in a neat manner. The height at the eaves will be determined by the type of bench to be used, but under no circumstances should they be under twenty-two feet. The roof should be of steel truss construction, with steel purlines, covered with roof boards, and then finally covered with slates, nailed down with copper nails. The roof must be provided with a large ventilator

through which the smoke will pass while the retorts are being charged. The floors must be of such material as to withstand the wear due to the use of heavy fire tools, and the action of heat and water. In one plant which the writer built, a paving brick made of slag obtained from the copper smelting furnaces was successfully used for this purpose. The retort house is sometimes provided with a basement into which coke is dropped when the charges are drawn from the retorts, so as to be handled without passing through the retort house, or charging floor. This is especially true in large plants, where stoking and charging machinery are used; but seldom practiced in medium-size works.

The Coal Shed should be so located that coal can be unloaded from barges or railroad cars directly into the shed by one handling, and its relative location to the retort house should be such as to require the least amount of labor necessary to bring coal from shed into the retort house; in so doing, in case it is necessary to cross any portion of the yard, the area way should be covered, for the protection of the workmen, and for keeping the coal dry during stormy weather. Coal sheds are usually of wooden construction, and should be weather tight.

(B.) The Exhauster Room is generally a continuation of the Retort House, and in small works where the stoker also attends the exhauster, a door in the division wall allows easy access to this room. Like the Retort House, this room must be of ample size. It should be wide enough to permit of additional apparatus being put in when needed, and long enough to have the apparatus in a continuous line. In this room are located the Exhauster and other apparatus needed for treating the gas before it reaches the purifiers. The floor should be cement, and the finish over underground pipes should be "sand jointed," so that in case it is necessary to take up pipes, it can be done with little damage to the floors.

(C.) The Purifying Room is usually a continuation of the Retort House and Exhauster Room, except in the case of large works, when there are sometimes two or more purifying buildings. Personally I prefer to have this building a continuation of the other buildings, as gas should pass from the scrubber to the purifier with as small a loss of temperature as possible, and this is not easily accomplished when the pipes have to pass underground from one building to another.

The Purifying House should be partitioned from the exhauster room with a solid wall, without openings of any kind. In this room are located the purifying boxes. The floor of this

building should also be cement, finished in a like manner to that of the exhauster room. These two rooms should be provided with ventilators, so that in case of a leak the gas will pass out of the roof. This is most important in the Purifying House, where seals are likely to be blown from back pressure. A liberal number of doors and windows should be built in the walls, and some of the doors must be of ample size to permit machinery being taken into the building.

(*D.*) *The Meter House*, in which the station meter is located, might be apart from the other buildings. This should be fire-proof, although wooden buildings are sometimes used. Ventilators in roof and plenty of side light should be provided. In small and even medium sized works, the superintendent's "works office" is located in this building.

Machinery and Apparatus. Beginning with the Coal Shed, we have the scale, track and truck with which coal is weighed and taken into the Retort House to be "charged" into the retorts. The weighing of coal is a very important matter, as it allows a company to find out the results being obtained from coal used.

In the first days of the invention, the retorts used were of iron, and were placed in a vertical position in the furnace. This was the mode of erection which would be naturally adopted at first, inasmuch as it lent itself to convenience in depositing the charge. But it was very soon found that the difficulty of withdrawing the residual coke was such that an alteration in the position was an absolute necessity. Accordingly, no long time elapsed before the retorts began to be laid, first at an inclination, then horizontally, and not only one, but two, three and eventually five, were set together and heated, at first by two furnaces, but later by one furnace only. At the present time, in some works of large size and capacity, settings of six, seven, eight, nine and even ten, retorts are in vogue.

The retorts of to-day are fire-clay receptacles, built into the furnace, and the whole called a "Bench."

"Benches" are of different types; those being universally used are the "semi-regenerative" or "half depth" type, and the "regenerative" or "full depth," and contain from five to ten retorts each. There are also "horizontal retort" types, and "inclined retort" types.

The former are those where the bench is both charged and drawn from the front, and the latter, as the name signifies, are inclined, and are charged from the upper end, and drawn from

the lower end by means of mechanical stokers, and are used only in large works.

Let us consider only the semi-regenerative horizontal type. A semi-regenerative or half depth type of bench is one which has the furnace located below the floor line of the Retort House, and has certain primary and secondary air ducts whereby the air is preheated before being admitted to the furnace, thereby producing better combustion. It is unnecessary to go into the details of construction, but it is sufficient to say that one of these furnaces will use at least fifty per cent. less coke to keep the retorts hot than the "old free-firing" type (which has not been considered in this article).

Another feature, and a very important one, is that a semi-regenerative furnace allows of a cheap grade of slack being used to fire the bench, thereby saving coke where there is a demand for same.

Above the floor line, and in proper position according to the designs of the bench builders, are located clay retorts, usually D-shaped, the rear of which is blind, and the front, or open end, provided with a cast-iron mouthpiece, equipped with a self-sealing lid, mechanically fastened. On top of these mouthpieces are spigot or bell openings, into which the standpipes connecting the retorts with the hydraulic main are placed. For a plant of the size contemplated in this article, benches of six retorts are the units I recommend. The standpipes are cast iron, and should be not less than eight inches in diameter, and made with the necessary curves, so that they will properly align with the hydraulic main, which rests on a suitable support on top of the bench, immediately above the mouthpieces. The hydraulic main is nothing more or less than a cast-iron or riveted steel box, sometimes cylindrical and sometimes D-shaped. The dip and seal pipes which connect the standpipes and the hydraulic main pass into the top of the main, through openings left for this purpose, and seal in the liquid in the main.

This apparatus gets its name "hydraulic" from the water seal in it. This water, or seal, is carried at a certain height, having an overflow and offtake, so that the depth of the seal is always maintained at constant level. Into this water, or seal, the dip pipe is extended to a depth not to exceed one inch. The function of the seal is to prevent the gas which enters the hydraulic main from returning down the standpipe when a retort is being charged. Apart from furnishing a seal, the hydraulic main becomes a receptacle for tar, which begins to deposit the

moment the gas strikes the water in the main. A tar overflow and offtake are provided, whereby the main is relieved of this by-product. These mains are generally provided with a partition, or diaphragm, so that they can be cleaned out at any time without shutting down the plant. From the hydraulic main, the gas is conducted by iron pipes to the holder, first passing through the different apparatus, of which the following are located in the exhauster room. One of the most important of these is the *Exhauster*.

Exhausters are of different types and makes, and it will only be necessary to describe the functions of this apparatus.

From the fact that the atmospheric pressure on the holder is greater than, or about as great as, what I may term the carbonizing pressure of the retort, it becomes necessary to produce a vacuum, by which means the atmospheric pressure on the holder will be removed from the gas works. This allows the gas to flow freely into the holder, so that an exhauster is installed immediately after the hydraulic main, and is operated at a vacuum whereby the U-shaped water gage shows a " level gage." This apparatus is generally operated by a steam engine, directly connected to the exhauster, and has a governor controlled by the volume of gas being made, which produces automatic regulation.

Immediately following the exhauster comes that apparatus known as a tar extractor, the one commonly known as the " P. & A.," named after the inventors, Pelouze and Auduin. The apparatus is made with two concentric cylinders, the perforations of 1-20 in. diam. in the outer one, being set staggered to the perforations in the inner one, so that the gas must impinge on the side of the inner cylinder, and thus deposit the tar. Gas manufacturing concerns in this country have ideas of their own, and to-day there are on the market tar extractors of great merit which are the results of experiments of these manufacturers.

After the tar extractor comes the air condenser. There is one concern manufacturing gas apparatus which holds a patent claiming certain advantages, and which places an air condenser between the hydraulic main and the exhauster.

Condensers are what their name signifies, and are of different types and construction, but whatever the type or construction, the functions are the same, and are as follows:

The extraction of tar and ammonia out of the gas.

The gas having passed through the hydraulic main and the P. & A. extractor has parted with the heavy tar and part of the ammoniacal liquor; then it becomes the work of the condensers to take out the remainder of the tar and liquor.

The gas is also allowed to be gradually cooled, for a sudden change in, or too low, temperature, will condense the light hydrocarbons, which are the life of the gas, or its illuminating power, and poor gas will be the result. Sudden cooling also tends to the formation of naphthalene, so that the process of cooling is generally controllable, and should be so arranged that when the gas reaches the purifying boxes, the temperature should not be lower than 60° fahr.

The early type was called the "atmospherical horizontal condenser," and is shown and described on page 76 of "Newbiggin's," from whom I quote as follows:

> "Its efficiency has not been generally recognized, owing to the want of a correct appreciation of the conditions on which the condensation of coal gas ought to be conducted, and this has led to its being generally discarded in favor of the 'vertical' form.
>
> "The earlier method of construction was to fix it against the outside of the wall of the retort house, or other convenient building; the several horizontal pipes rising with a slight inclination one above the other (to allow of the flow of the condensed products), the ends being connected by U-shaped bends."

From these early types of condensers, the present-day condenser is the result, although horizontal pipe condensers are still in use.

In a works of the size under consideration, the condensers should be what is known as the "multitubular" type, which is described as follows:

A riveted steel shell of cylindrical form and of like construction to a return flue boiler is made; a certain number of steel tubes are expanded into a special head, and through a properly constructed air duct the atmosphere is allowed to enter at the bottom, flow through the tubes, and pass out of the top through a tampion to the outside of the building. The hot gas enters into the top of the condenser, and passes downward, and in so doing comes into contact with the air tubes, and thereby is lessened in temperature, which causes the tar and other impurities to precipitate and flow away through proper vents provided for this purpose.

A water condenser is also used. This is of like construction, only that water instead of air is used, and the flow of water and gas is in the opposite direction to that of air and gas in the other condenser. These condensers are set on end, and water and other pipes are connected where necessary. The sizes of the

shells, or cylinders, as well as the number, length and diameter of tubes, are governed by the capacity needed.

In some plants, a washer is placed between the water condenser and the first scrubber. There are washers and washers, and my experience has been that they are tough customers. One should be careful in selecting a washer. They get clogged up with naphthalene, occasioned by a sudden change in temperature of the gas, which, in small works, is due to the workmen letting too much cold water into the washers. My experience has been that the ordinary square, or box-shaped, washer, which is sold by manufacturers for small plants, is only a waste of money. Then there are rotary and other washers, which are all right for large plants, but even they are not for the small plant.

After the washer, if one be put in, come the scrubbers.

These are of like construction to the condensers, but instead of tubes, angular rings are riveted horizontally on the inner side, to support trays on which coke is placed, and through which the gas is forced, so that any particle of tar which may have escaped the other apparatus is arrested and removed.

Like the condensers, the scrubbers stand on end, on proper concrete bases, or foundations. There should always be two scrubbers, so that one can be in use while the other is being cleaned out.

All of the apparatus, from and including the exhauster to the scrubber, are provided with overflows or offtakes, which are connected to a pipe leading to the tar well, through which tar and other condensation is removed.

The pipe line leading from the hydraulic main to the purifying boxes might be termed one continuous line, provided with T's at the proper places, so as to connect the different apparatus hereinbefore mentioned. Between each T a valve commonly termed a "by-pass" is placed. To each apparatus there are two T's in the main line, one for the inlet and one for the outlet; and both the inlet and outlet are provided with a valve.

These three valves in connection with each piece of apparatus are used in the following manner:

The valve between the T's on the main line, called the "by-pass," is closed, thereby compelling the gas to pass through the apparatus when in use, but when it becomes necessary to clean out an apparatus, say, for instance, renew the coke in a scrubber, the by-pass valve is opened, the inlet and outlet valves closed, and the gas passed by the apparatus.

From the scrubber the gas is conducted into the purifying

boxes, of such size and capacity to purify a given amount of gas in twenty-four hours. These boxes may be constructed of cast-iron, steel or reinforced concrete, the writer favoring cast-iron boxes.

The form of cast-iron box most generally in use is rectangular in shape, and consists of two parts. The lower part with sides and bottom, but open at the top, has cast with it a concentric rectangle, some two inches larger, which extends from a level with the upper edge of the sides down to a point midway of the sides. This forms a channel around the outside of the lower part, which is filled with water to make a lute, or seal. The upper part is made of sheet steel an inch larger all round than the lower part, and is built with a top and sides, but open at the bottom. The lower edges of this enter into the water and are prevented from rising above a fixed point by means of clips.

The type of box above described is known as a wet seal box. A dry seal box has a flat steel top, which fits down on a rubber gasket and is bolted in place.

The interior of all boxes is arranged with trays to hold the purifying material, which may be either oxide of iron, commonly known as "iron sponge," or else slack lime, the cost of which in some locations proves excessive when compared with iron sponge.

Purifying boxes should never be less than two in number in any plant, and should be provided with the proper valves and by-passes, whereby one box can be in use while purifying material for the other box is being revivified.

In a great many works, what is known as a "three-way," and sometimes "four-way," valve, of very ingenious construction, is placed between the boxes, by which means the flow of gas can be reversed, and the life of the purifying material greatly lengthened.

In some works, the purifying boxes are located on the second floor, and through holes in the bottom of the boxes, provided with proper covers and fasteners, the purifying material is dumped to the floor below.

The covers of all boxes are handled by means of some type of lift, and the plant under consideration will have an I-beam track, the ends of which will be built into the side walls, provided with a $1\frac{1}{2}$ ton Yale & Towne Chain Block, attached to a trolley, which will move along the I-beam track. By the use of this outfit, the box cover can be raised clear of the boxes, and moved out of the way when desired.

The purifying boxes are filled with purifying material, whether it be lime or iron sponge; the gas is made to pass through the material, and sulphureted hydrogen and other impurities almost entirely removed.

If lime is used it is generally thrown away after it becomes foul; although, in many instances, it is used for and makes a very valuable fertilizer, due to the ammonia contained therein.

When iron sponge is used it is dumped on a floor, and is properly spread out and turned over daily, until the impurities are absorbed by the atmosphere; after a certain amount of such treatment, it is again ready for use.

In purifying the gas, tests should be made at least once every twelve hours to determine whether or not purifying material is becoming dirty, thereby allowing foul gas to go into the mains. These tests are generally made through a pet cock, placed on top of the purifying boxes for this purpose. In making these tests, two elements of impurities are looked for. The first is sulphureted hydrogen, which is discovered by moistening a piece of writing paper with a solution of acetate of lead, in distilled water, and exposing it for not less than a minute to a jet of unlighted gas, obtained through the pet cock, on top of the purifying box. If sulphureted hydrogen be present the paper will become browned or blackened, and on the first trace of this impurity the box should be thrown out of commission, and purifying material removed and revivified.

The other test is for ammonia, which is made in a similar manner as for that of sulphureted hydrogen, yellow turmeric paper, slightly moistened with water, or blue litmus paper being used instead of acetate of lead.

If ammonia shows up in the test, and sulphureted hydrogen does not, then the trouble must be looked for in the condensers, washer and scrubbers, and steps taken to remove it before it reaches the purifying box.

In *Newbiggin's Hand Book* we read: "By the acts of Parliament, all gas supplied must be wholly free from sulphureted hydrogen. Also, the maximum amount of ammonia shall be four grains per one hundred cubic feet, and sulphur compounds (other than sulphureted hydrogen), the least amount with which gas shall be charged, shall be seventeen grains in every one hundred cubic feet of gas."

From the purifying boxes, the gas passes through the station meter, and the quantity of gas manufactured and passed into

the holder, after its purification has been completed, is measured and recorded by this meter. This is invariably of the wet type; that is to say, the measuring wheel is caused to revolve by the elastic force of the gas pressing upon the surface of the body of water, with which the vessel is filled up to a certain line. This meter is generally a cast-iron cylinder, with a measuring wheel on an axis, containing a certain number of measuring drums. Connected to this axis is a train of clock-work, properly proportioned and connected to the dials of the meter, which registers the gas as it passes through.

A very important feature in such a meter is to see that the water line is carried at a correct level, for a meter can be made to register fast or slow, if a false water level is carried, and the writer has known of cases where the work's foreman raised the overflow-offtake, and ran more water into the meter, raising the water line, thereby decreasing the capacity of the measuring drum, and passing a lesser amount of gas through; while the registering of the meter could not be changed, and the result was more gas was registered as being made than was made.

The duty of the station meter is that of a "silent sentinel," keeping watch day and night of the amount of gas made, so as to enable the management to determine first of all the value to the company of the coal being used, and also the amount of leakage and condensation to which a company is subject at all times. From the station meter the gas is conducted into the holder, and is ready for distribution.

In the meter house, a pressure recording gage, as well as a photometer of some make should be placed, so that the workmen may be able to watch the candle-power of the gas being made.

When coal is being carbonized for the first hour or two, the gas is very rich, after which it becomes leaner and leaner all the time, until "marsh gas" is being thrown off, and as this is very deleterious to the gas, it is necessary for the workmen to know this, and there are two channels through which it can be done. One is, to watch the clock, to see that the charges do not remain in the retort longer than is proper, and next is to watch the photometer.

There are times when the governor of the exhauster gets out of order, and does not act automatically, thus allowing the exhauster to show a vacuum instead of a level gage, which tends to pull furnace gases through any cracks there may be in the retorts, thereby reducing the candle-power, so that it is very

important that the workmen should have some apparatus to govern them as to the candle-power.

From the fact that all of the retorts in the benches are not charged at the same time, it will be appreciated that rich gas and lean gas are being made simultaneously, which keeps the candle-power up to the average, and in some cases where the standard candle-power is high and the coal will not yield this standard, some cannel coal is used for enriching the gas.

A " pressure board," containing pressure gages, piped back from each apparatus, should be located in the retort house, whereby workmen could know at all times whether or not there is back pressure on any of the apparatus. Should the distribution system be a high-pressure one, the booster, or compressor and tank, can be located in a room adjoining the meter house.

Holder. A gas holder, or a gasometer, is a receptacle in which gas is stored, and from which it is allowed to flow into the street mains and to the consumer, giving the company what the electric companies have been striving for years to attain, and that is, a means of storage. The electric storage battery has partly but not fully met this need.

A gas works, sending out 100 000 ft. of gas per twenty-four hours, the majority of which is sent out during " peak load " period (say, for instance, that 75 000 out of the 100 000 ft. of gas is sent out between 6 P.M and midnight), can, with a carbonizing capacity of 50 000 cu. ft. or even less, during this period, take care of this peak load, as the manufacture of gas would be carried on throughout the twenty-four hours per day, and when the gas is not being used, it is being stored in the holder for the " peak " period.

I heard an Irish works foreman once describe a gas holder in the following manner: " It was a tank with the bottom at the top."

A single lift gas holder comprises an uncovered cylindrical reservoir, in which water is placed, commonly called " the tank," and a cylindrical holder, slightly smaller than the tank, made out of riveted sheet iron or steel, having sides and a top, and placed in a vertical position in the tank. It is supported by columns or guides to keep it in this vertical position.

Holders having more than one lift have as many steel cylinders as there are lifts, the inside cylinder only being provided with a cover. The others are open top and bottom, and at the lower end have a cup on the outside, which is always full of water. In rising, this engages a similar inverted pro-

jection on the inner side of the next larger cylinder, thus forming a seal.

The gas is allowed to enter under the holder and above the water line by means of the inlet pipe, the lower part of the sides of the holder being immersed in the water, making a seal, which prevents the gas from escaping, and as a result the expansion of the gas as the volume is increased causes the holder to rise.

Holders are of two types: The first, called a " pit holder," where a pit is dug in the ground, and a tank of either brick or concrete construction is made to contain water in which the floating holder rises and descends; the other type of holder, called the "steel tank holder," where a heavy riveted steel water tank is built on a concrete foundation, entirely above the ground, and in which the holder floats. The latter type of holder is now almost universally used, from the fact that the tank, or underground storage, requires a very uniform and stable foundation to prevent settling. In some instances, the cost of preparing the foundation by piling, etc., has been very great, whereas in the case of the steel tank construction this is not necessary.

Presuming that the steel tank construction will be adopted, we will not consider the other type.

The substratum should be investigated so as to determine the depth to which the foundations should be carried, and after this has been done a foundation of cement concrete of sufficient strength should be put in, the upper surface of which should be finished level and reasonably smooth. The necessary pit through which the inlet and outlet holder pipes pass must be provided.

A holder being of standard design, it is unnecessary for me to go into details of construction; it is sufficient to say that the gas engineer must carefully scrutinize the drawings and specifications of the builder. The size of plates, angles, rivets, etc., must be considered, and the columns and carriages, stays and wind braces, require particular attention.

The crown of the holder must be provided with a manhole and cover, and a blow-off cock.

The center post must be properly fastened, so as to take the weight of crown when holder is empty, thus relieving the side plates.

A number of landing blocks must be provided, and properly fastened, on which the holder rests when empty.

The inlet and outlet pipes must be installed, having drip pots and pump connections, and the pits must be covered.

Ladders and other necessary adjuncts must be supplied,

whereby workmen can get from base to top of holder, and be able to walk around the top edge of tank.

A steam connection must be made with the boiler, so as to keep the water in the tank from freezing.

If the holder be of two or more lifts, care must be taken to see that the guide wheels are properly set, and fastened, so that the different lifts will always cup, and flexible steam pipes must be connected, so that the water in the cups will not freeze.

The number of coats of paint, as well as the quality and manner in which they are put on, must have attention.

After completion, the tank must be filled with water, tested for tightness, and all leaks stopped.

Then the holder must be filled with air, and also tested for tightness, and leaks must be located and stopped. Leaks in the holder are discovered by using a shaving brush and a cup of soapsuds.

Of course, the engineer is not called upon to do this manual labor, but he must watch the work, and know that it is being properly done.

A tar well and pump must also be provided to take care of the tar.

Distribution System. We now come to the Distribution System, which can be either low or high pressure.

If low pressure, the mains can be of bell and spigot cast-iron pipe, with leaded joints, and must be of ample size, so as to give good service.

If high pressure, they can be cast iron, using universal pipe, or of threaded iron or steel pipe.

In determining the system to adopt, care must be exercised, as there are several elements to be considered.

With the low-pressure system, a booster, or compressor and tanks are not necessary, and the cost of these apparatus as well as the motive power needed to operate them is saved, also the cost of governors on each service; but against this system one has to charge the cost of large mains, necessary to pass gas at low pressure, say, one-half pound per square inch.

With a high-pressure system smaller mains can be used, as the greater the pressure, the larger the volume which can be passed, but against this cost must be charged the investment in compressor and the operating charges, as well as the service governors.

Experience has shown that high-pressure distribution is successful, and in many cases desirable, and, in the writer's

opinion, the only element that need be taken into consideration is "alkali" in the ground, the attacks of which only cast-iron pipe will effectually withstand.

In laying out the "mains" system, a careful study of the present as well as future requirements must be made, so that extensions can be made at the least cost. A company never feels like putting in mains the size of which appear too large for the business in sight, but experience has taught that a 4-in. pipe laid at the time the original main system is put in is a great deal more economical than a 3 in. to be replaced in five or ten years.

The cost of ditching is the same for 3-in., 4-in. or 6-in. pipes, and the difference in cost between 3-in. and 4-in. pipe is so small that it is scarcely appreciable. When a main has to be taken out and a larger one put in, the expense necessary to disconnect and reconnect the services is very great.

Services. Like the mains, services can be of smaller size pipe in a high-pressure distribution than in a low-pressure.

All services should drain from the meter to the mains, so that condensation will flow into the mains (and be removed through the drip pots), and not into the meter.

All valves should be provided with boxes, coming up to the street surface and marked "Gas."

Services should be tapped in the top of main, two street L's being used to provide a swing joint to take care of expansion.

All services should have a curb cock and box marked "Gas."

Having determined the system, care must be taken in laying the pipes, more especially if the low-pressure system is adopted. Mains must be laid so that the pipes rest uniformly on the bottom of the trench, and they must be so graded that any condensation forming in the mains will flow to a common point, at which a drip pot is located, so that it can be pumped out.

In laying of cast-iron gas mains the same methods are adopted as in laying water mains, only be sure to have plain or uncoated pipe, for if there is a coating on the pipe, a tight lead joint can never be had.

Cast-iron pipe for gas mains is not as thick, and does not weigh as much to the foot, as water pipe, therefore the cost is less. One advantage of using cast-iron pipe as against threaded pipe is that it will permit of tapping for the service connections. The standard wrought-iron pipe is too thin to be tapped, and a saddle must be used. This saddle is usually placed on the main, with a rubber or other gasket which in time will become leaky,

and, when streets are paved, makes repairs expensive. To get out of the use of saddles, extra heavy threaded pipes must be used.

Where a high-pressure system is adopted, and screwed pipes used, it is necessary to have expansion joints at intervals, and it requires careful study to determine these locations. I have seen a 4-in. threaded gas pipe, in a northern state, pull apart three inches in the month of May. Condensation and pumping of drips is less frequent with high pressure than with low, as a great deal of the moisture is taken out of the gas during compression. Naphthalene will, however, form in some places during extreme cold weather, which will be turned into liquid in hot weather. It generally finds its way into the drip pots, where it must be pumped out, for if allowed to collect it will form a trap, and stop the flow of gas.

When it is borne in mind that a gas leak means a continual loss to a company, the necessity of laying a substantial and well-constructed pipe line will be appreciated, and in the writer's opinion this is one of the points in which many gas companies are weak. I know of several small plants where the leakage amounts to from twenty to thirty per cent. of the gas made, and was told, after recommending that steps be taken to stop this great loss, that "it was cheaper to stand the loss than pay interest on the amount necessary to stop the leaks." There is no telling where the troubles due to a gas leak will end. In many instances, shade trees are killed, and the owners "get sore" at the company. In northern climates, where frost gets into the ground for a depth of several feet, escaping gas finds its way through the service ditch into the basements of stores, and dwellings, and the leak must be stopped.

I recall two cases which happened in winter, while I was in charge of the Butte Gas Company, in Montana.

In one instance, owing to the absence of a record of the mains, which were laid years before I became associated with the company, the workmen had to dig over one hundred feet along the ground (which was frozen over seven feet deep), before the main was located. The service was a "split" one, and did not run directly from the main to the building, so that digging along the services did not help. When the main was found, it was seven feet below the surface, and the digging was still in frost. Those having experience with work in such a climate will appreciate the cost. Many cords of wood were used to "thaw out," and day and night shifts were employed.

The other was on a granite-paved street; while the workmen were digging, a bystander lighted a cigar, dropped the lighted match along the edge of the wooden sidewalk, and an explosion occurred that lifted him, and twenty feet of the sidewalk, into the street. The company that does not think it of sufficient importance to stop leaks will always end in the poor house.

Therefore, a correct map of the town, on a fairly large scale, should be made, and on it should be shown the location of all mains, services, valves, drips and specials. A note-book or key should be kept, showing the exact location of the pipe, specials, etc., giving at least the distance from two fixed points, so as to permit of their being easily located.

Meters. The consumer's meter is the "sentinel" which tells the company of its earnings. The dry meter is universally used for this purpose, and is considered one of the "most ingenious measuring apparatus of this, or any past, age." It therefore behooves me to describe this meter.

A dry meter is usually made of tin, molded into the shape of a rectangular box. This is divided into two compartments by a central partition, and has two movable diaphragms with prepared flexible leather sides. The gas enters and leaves these compartments alternately, through valves, whose construction and operation are similar to those of the slide valves of a steam engine, and whose passages are made to open and close at the proper time. The alternate expansion and contraction of the inner and outer spaces (after the manner of the ordinary bellows), by the pressure of the gas extended on the surface of the diaphragms, are communicated, by levers and cranks, to a train of clockwork, comprising the indicators and registering dials.

The gas meter is the most positive measuring apparatus, outside of a wooden or metal measurer, and can be made absolutely accurate in its measurements. Meters are tested from time to time, and if found incorrect, they are corrected by shortening or lengthening the lever arm, as required. If a meter is found two per cent. fast or slow, it is never changed.

Newbiggin says, "Meters, as tested under the provisions of the 'Sales of Gas Act,' 1859, are stamped 'Correct' by the inspector when their registration does not vary from the true standard or measure of gas more than two per cent. in favor of the seller, and three per cent. in favor of the consumer."

The Commonwealth of Massachusetts practically leads in the regulation of certain features of the gas business, and Mooney says, "From the reports of meter inspections in Massachusetts,

some ideas are gleaned in regard to the reliability of that much-abused instrument" (meaning the gas meter).

"For the year 1885, the number of old meters inspected was 178. Of this number, 51 registered against the consumer, the average error being 4.22 per cent. One hundred were within the limitation allowed by law, namely, 2 per cent. either way; 25 registered against the companies, the average error being 5.02 per cent."

"The average error of all the above meters tested was 0.58 of 1 per cent. against the consumer. Other meters leaked, and others would not register."

"Taking the years from 1872 to 1881 inclusive, the percentage of fast, correct and slow meters complained of is as follows:

"Fast, 934; correct, 1 148; slow, 361; total number, 2 444."

Like other gas apparatus, the meter has been improved upon since 1881, and naturally complaints are fewer; my only reason for quoting Newbiggin and Mooney is to show that from the very early stages of the industry the customers' *interests* were looked after.

The testing of a gas meter is a trade in itself; still, a gas engineer should be familiar with the methods, and be able to determine whether or not the "meter tester and prover" are doing good work. From the fact that an article can be written on the subject of testing meters, I will not attempt to discuss this branch, but will say that it is an important one, and needs careful attention, as the gas meters are often slow, which means loss of revenue.

Before entering upon the manufacturing and commercial ends of the business, it might be well to deal with the channels through which the revenue is derived, which are, — 1. Illuminating. 2. Fuel. 3. Power. 4. By-products.

Beginning with illumination by gas, we are told that in 1798 lighting by gas was an accomplished fact, and we will follow this, step by step, to the present time.

The first burner was of iron, and was supplanted by the "lava tip," in a brass ferrule, sometimes called the "fish tail burner," which is still in use, and was followed by other lights of various designs, introduced by Sugg, Cowen, Bray, Strode, Wenham and other makers. Newbiggin says, "Gas burners are made with a precision unknown in the early days of gas lighting, and great improvements have been effected in their construction."

The Bray burner, as an open burner, and the Welsbach mantle burner, are practically the standard burners of to-day.

The Welsbach system of incandescent gas lighting marked a notable advance in artificial illumination. It consists of a Bunsen burner, over which is suspended a mantle, composed of a textile filament, coated with certain rare refractory oxides. These lamps are so universally used that it is hardly necessary to further describe them, other than to say that as against an open flame, consuming 5 ft. of gas per hour, and giving 16 candle-power light, a Welsbach incandescent burner, consuming 3 ft. of gas per hour, will give 60 candle-power light.

Immediately preceding the invention of the Welsbach burner, the Sugg's Argand burner was the ideal burner, and Sugg's London Argand, No. 10, is the standard by which light is measured.

The art of proper distribution of light is too broad to be dealt with in this article, so I am going to confine myself to the statement that the use of an inverted mantle lamp allows of what is known as " indirect " system of lighting, where the lamp is hid by a reflector which throws the light against the ceiling. The decorative uses to which gas may be put is a surprise to those who have come to believe that artistic lighting effects can be obtained only through the medium of electricity. Electricity, with its many possibilities, called out numerous arrangements, and it also gave a spur to the perfecting of gas as an illuminator. This has been carried to such a point that to-day only an expert can tell whether the light flooding an apartment comes from electricity or gas. The brilliance and steadiness of the one are matched by those of the other, whether in a large public hall or used to dispel the darkness in a room of ordinary size.

The lighting fixtures also are just alike. The globes and attachments are the same for each. Even the heavy chains from which the beautiful dome and shower lights are suspended, and which have been supposed to belong to electricity alone, are made to sustain gas as well as electric fixtures. The closed round globe, with which the modern gas light is protected, and the invention which permits it to project upward or downward, or to be turned to any angle, makes it possible to use gas in practically every way in which electricity can be used. It lacks no detail of brilliance, elegance, convenience or ingenuity. With the little devices for lighting gas that have recently been put on the market, even the inconvenience of matches, which has often been urged against it, is overcome.

The use of gas in the home is constantly growing. More and more ways in which it can add to beauty or comfort, or both, are being discovered. Gas grates have been known so long that they have ceased to be a novelty. In those sections of the country where natural gas can be obtained, gas is used freely in ways that are unthought of where only the manufactured product is known, but even there, the numerous ways in which gas can be applied to the needs of the home are largely unknown. A new patent is the gas radiator. It is set in a room as is any radiator, and can be run by gas or attached to a hot water or steam heating plant. Then it is used as any other radiator would be, but in the spring and summer, when there is no thought of heating the whole house, yet there is chill enough in the air to make a little artificial heat desirable, the gas can be turned on, and the room in which the radiator stands made to be warm and cozy. Two or three of these in the house add a great deal to the general comfort.

Fuel. The use of gas for cooking and heating has made rapid strides in the past decades. For handiness in application, and cleanliness and cost, gas, as a fuel, is unsurpassed. The use of gas in a kitchen allows the housewife to sleep at least half an hour longer in the morning; lessens her daily toils by eliminating the packing in of coal and out of ashes, splitting of kindling, to say nothing of the saving of labor in keeping the house clean, due to the absence of smoke and dust. Gas cooking stoves have changed remarkably. Some with low ovens are still seen, but practically all of them are built as a table, with lids, broilers, ovens and warmers all elevated from the floor, so that there need be no stooping. A shelf across the lower part is convenient for spoons or other utensils needed in cooking. In many instances, the doors to ovens and broilers are fitted with glass, so that the cook can see at a glance how things are going inside, without waste of time or energy in opening and closing doors, and with little likelihood of things burning because they have been left a moment too long. Some stoves are so made that they can be used with coal or gas, which is a convenience appreciated, especially in the natural gas regions, where there is sometimes a shortage of gas supply.

As compared with coal for fuel, at $5.50 per ton, and gas at $1.10 per 1 000 cu. ft., the following are the results of a test made by a well-known authority.

"A leg of mutton weighing 8 lb. 10 oz. was cooked in two hours and twenty minutes, losing 7.5 oz., 41 cu. ft. of gas being used, at a cost of 4.51 cents."

"A leg of mutton of the same weight was cooked in the oven of a coal stove, at a loss of 8.75 oz., and the cost of fuel was 7.72 cents."

"A rib of roast beef weighing 11 lb. was cooked in a gas stove, the loss being 14.5 oz., using 40 ft. of gas, the cost being 5.28 cents."

"A rib of beef weighing 13 lb. 2 oz. when cooked in a coal stove lost 15 oz., and the price of fuel was 8.01 cents."

From the above, it will be seen that the advantage is decidedly on the side of gas, as far as the actual cost is concerned, with the additional one that immediately the cooking is over, the gas is turned off, and there is no future consummation and waste, as in the case of cooking with a coal fire. In cooking meat by gas, it is roasted, not baked, as in the common cooking oven; the difference being in baking that the meat is excluded from the air, while in the case of the gas stove it is exposed to a continual current of air, which gives to roast meat that peculiar flavor which baked meat has not.

Appliances for heating water are almost as numerous as the different makes of stoves, and each one has its special claim to attention. That which supplies continuous hot water is a luxury which all appreciate, but there are others which serve practically the same purpose, at a considerably less expense. One, attached to the boiler, is so regulated that it will heat any quantity of water desired in a few moments' time. Enough for the washing of dishes can be obtained in four minutes; for the bath in eight or ten; for the laundry in fifteen minutes. The attachment can be kept going all the time, or for any length of time, or lighted only as the water is used.

Another useful application of gas is in the destruction of garbage. It is predicted that it will not be long before every private house will install an incinerator as a necessary part of its equipment. It can be connected to a chimney flue in conjunction with a range, or a smaller size can be located directly within the chimney base, only the face showing in the room. It is cleanly, sanitary and convenient. Its general use would eliminate the garbage wagon and garbage cans, so offensive on city streets, while in the country, where such conveniences do not exist, the incinerator meets a need that has long been felt.

Of all the departments in a house, the laundry now claims the greatest attention. Formerly, two stationary tubs in the cellar, with hot and cold water, a low laundry stove and a cement floor, with good light and ventilation, and convenient arrangement of the artificial illumination, were deemed to comprise a

model home laundry. They do make an excellent one, but improvement is rapidly taking place. The tubs are supplemented by a washing machine which minimizes the labor of wash day. A late invention utilizes the waste heat from the laundry stove, on which the clothes are boiled, and the irons heated, for drying the cloths by means of a drying closet, and the moisture, odors, etc., emanating from the clothes are carried away.

There is an ironer run by gas, which simplifies this part of the household labor. On it can be ironed all the plain clothes, many pieces of underwear, hosiery, kitchen aprons, bed and table linen, such as doilies, centerpieces, dresser scarfs, curtains, — probably eighty per cent. of the family wash, — and in one fifth the time it would take to do it by hand.

The gas iron is another convenience. It obviates the running back and forth to change from one iron to another, gives an even heat, wastes no gas, and is so constructed that the handle of the iron is always cool.

Power, etc. In producing power, the gas engine plays an important figure. While most modern factories are being equipped with individual motor drives, electricity not being a primary power, the generators have to be driven by steam, water power or gas engines. With the invention of gas producers, gas engines, of units as large as 3 000 h.p. each, are being used. While such size units are not admissible in our 30 000 city, gas engines up to 200 h.p. are not uncommon installations. In many instances, the gas company owns and operates the electric-light plant, and uses gas engines for this purpose.

By-Products. I have already said that the market as well as price obtained for coke and tar is no small feature in the earnings of the company. When there is no market for coke the company has to devise ways and means of working up one, which is by no means difficult. Coke is introduced into laundries and houses. I know of instances where a company purchased and rented coke-burning laundry stoves to Chinese laundries to start them using coke, which met with a great deal of success. Coke is reduced in size by means of some form of mechanical crusher, and sold for domestic fuel, to be used in furnaces; especially those of "hot-air" type, base burning stoves, and in laundry stoves, and makes a good substitute for hard coal. In northern latitudes, considerable coke is used in salamanders during the winter months, for drying out plaster in new buildings.

In towns where hard coal sells for $10.00 per ton, $8.00 per ton can be gotten for good, clean, crushed coke.

To-day, gas-house coke is being treated by a process whereby it is enriched, and more heat units, as well as better results in burning, obtained. This is an English invention, and the coke, when treated, is known as "Charco."

"Charco" has been a subject of close investigation in London, and I will give here an extract from report on a series of tests, carried out in June, 1910, under the direction of the Coal Smoke Abatement Society, of London, England, who describes Charco as follows:

"Charco," judged from the sample submitted, is a fuel almost similar to coke in appearance, and of about the same density. An analysis of the sample tested was made by Mr. B. H. Stanger, for the society, and it was found to have the following compositions:

Ultimate Composition.

Carbon	88.80
Hydrogen	0.89
Oxygen	1.53
Nitrogen	1.58
Sulphur	0.90
Moisture	2.10
Mineral matter (ash)	4.20
	100.00

"The calorific value was 13 342 B.t.u., equal to 7 412 calories."

With this improved method of producing coke, there seems to be no reason why a market should not be found at all times and in all places.

In a plant of the size I have in mind, the other by-product will be tar.

Tar is used to a great extent in making gravel roofs for buildings, in prepared roofing and other building papers, and with the advent of good roads, millions of gallons are being used in the production of different road building material. In places where the demand for coke is good, and for tar poor, tar can be burned in the furnace, in place of coke, and all of the coke sold. Where a company owns and operates the electric-light plant by steam, tar can be used under the boilers, instead of coal.

In many large works, ammonia stills are installed, and ammonia concentrates are obtained, but our plant is too small to consider these by-products.

Another source of revenue is that of handling and selling gas appliances, such as stoves, fixtures, lamps, etc., as well as piping of houses. In many towns quite a revenue is derived from this source, but in the small town, if a company can "break even" in handling this branch of the business, I think it advisable.

Having covered the works, mains, services and meters, and channels through which revenue is derived, before going into the commercial end of the business, I will endeavor as briefly as possible to tell something about the use to which these component parts are put and the manner in which the plant is operated.

Manufacture. The most important factor is coal, a knowledge of the character and quality of which is most important to a gas engineer and manager.

The following are a few of the principal elements and products whose value affect and determine the relative values of different kinds of coal.

A. The amount of gas which can be distilled out of one pound of coal.

B. The illuminating power of such gas produced by each ton of coal carbonized.

C. The amount of coke which can be obtained from each ton of coal carbonized.

D. The amount of tar which can be obtained from each ton of coal carbonized.

E. The amount of ammonia, and the strength of same, which can be obtained.

F. The amount of impurities, such as sulphur, carbonic acid, etc., in the coal.

The coal most used for making gas in this country is known as "Youghiogheny," mined in the district of the same name, in Pennsylvania.

At the mines located at Sunnyside, Utah, a very excellent grade of coal is mined, which compares very favorably with the Pennysl vania coal.

All of this coal is what is known as bituminous.

In certain coals when the value known as illuminating power is low, "cannel" coal is used as an enricher.

Cannel coal is always high in volatile hydrocarbon, and low in fixed carbon, so it is only used in small quantities as an enricher.

A gas engineer is sometimes called upon to judge the value of coal at sight, and there are certain characteristics with which he must be familiar to enable him to do so, among which I may mention —

Luster: All gas coals possess a degree of luster more or less bright, but there are some coals having a bright luster which are unfit for gas purposes, and experience can alone detect the difference.

Fracture: The distinguishing mark of which will show, when gently broken, either cubical or angular forms, and present a fine pitchlike appearance.

The detection of sulphur is sometimes hard, although some coals are so full of it that the yellow streaks are easily discernable.

While a coal might run high in volatile hydrocarbon—gas—(take, for instance, cannel coal), it might be unsuitable for use in the manufacture of gas, due to the low yield of fixed carbon, — coke, — and it might be well to give here the analysis of a good gas coal.

Bituminous:

1.	Fixed carbon (coke)	60.0 per cent.
	Volatile matter	34.0
	Ash	03.0
	Sulphur	01.5
	Moisture	01.5
		100.0 per cent

While that of cannel coal is

2.	Fixed carbon	23.50 per cent
	Volatile matter	58.00
	Ash	18.50
		100.00 per cent

In case No. 1, 60 per cent. of fixed carbon — coke — is a valuable by-product, while in the case of No. 2, the 23.50 per cent. of coke is absolutely worthless.

A good gas coal should yield 4.8 ft. of gas per pound of coal, 1 200 lb. coke, and 12 gal. of tar to the ton coal.

Coal for a plant such as I have in mind should be shipped by rail and shoveled from the cars into the shed, from which place it will, after being weighed, be taken into the retort house and made into gas.

The cost of such coal depends on the locality, and ranges from $2.50 to $5.50 per ton in the shed.

Having obtained a proper grade of coal and a fairly good supply on hand, the plant complete, mains laid, meters set, all the engineer or manager has now to do is to " get busy " and earn dividends for his company. To do this it behooves him to have

competent help, the most important of which is the stoker. He is the "whole works." He must be a man of even temperament, and one who can stand hard, hot work. My experience has been that the best stoker is the man not afraid to work, who wants a steady job in the town in which he resides. It is a mistake to take a stoker from one town to another. He is never satisfied. To him, the "works is not just as good as the one he left"; "the coal is not the same"; in fact, he is never satisfied, and after a brief period, he "goes back home." To get stokers, the engineer must be able to train them, "break them in," and this is no small job; but once broken in, the stoker will never turn to any other work, for his duties are as regular as clock work.

A handy "yard man" must be employed, one who will attend to changing of purifying boxes, pumping of holder drips, attend to pumping of tar, and weighing and delivering of coke; he will lend a hand to the stoker in "a pinch."

The amount of help needed around the plant is four stokers and a yard man, all of whom will be under the engineer and superintendent.

Have secured the force, the manager will begin the manufacture of gas.

Presuming that the plant is "brand new," and is just being started up after the completion of the benches, a slow wood fire is made in the furnace and a drying-out process is begun, the fire being kept going night and day, and increased daily, until the "heats" begin to rise, and after the retorts show signs of being red a small charge of coal should be put into them to prevent damage. After the fire is once started it should not be allowed to go out, as "up-and-down heats" are very detrimental to the bench. When the retorts have attained a certain heat, then "charges" are regularly made and the proper amount of coal to charge two or three retorts at a time (as the case may be) is brought in and used. After the heats are up, and the charges are regularly made, then the "works" is in full operation.

Mention has been made of a scale in the coal shed, so that we will start in by having the stoker fill his car with coal, weighing the amount necessary to charge a number of retorts. If the bench is a full or half depth 6's then three retorts should be charged every four hours. In charging retorts while making gas, care must be taken to slack up the lids of the mouthpieces and apply a lighted torch so as to ignite the gas in the retort, for if this is not done the inrushing oxygen will produce a very severe explosion which tends to damage the retorts, to say noth-

ing of burning the stokers. Be sure to have this done, then open the retort and by means of the rake draw out the coke, which is red hot. It is at this stage of the game that the hard, hot work comes in.

After the charge has been drawn, a " charging scoop " is used to throw the coal into the retort. " In throwing the charge " considerable skill is necessary, and only practice will allow the stoker to throw the charge evenly from the back to the front of the retorts. If this is not done, and the charge " bunched," the coal will not yield the proper amount of gas in a given time, and gas is lost, heats go down, and poor coke is the result. After the charge is " thrown " and the retort sealed up, the stoker proceeds to fire the furnace with a part of the hot coke, then wets down the balance until all the fire is out, and wheels the coke out to the coke shed. The stoker sees to the cleaning out of the furnace and removing the ashes and clinkers. He also takes care of the boiler which supplies steam for running the exhauster and heating the buildings, and he attends to the care of the exhauster.

Usually he is an intelligent man, one who is able to read and write, and he keeps tab on a slate of the amount of coal charged, and coke " wheeled out " on his shift, and generally, for his own satisfaction, reads and makes a record of the station meter at the beginning and end of his shift. A stoker is busy every minute of his shift, and only in cases of stopped standpipes does his work vary from that of the clock.

After the retorts have been sealed the distillation of the coal immediately begins, and the gas rises from the bench to the hydraulic main, — the functions of which, as well as those of the other apparatus, have already been explained. At the hydraulic main, and even up to the tar extractor, the gas is visible, being of a slate color, but after the condensers have been passed, it becomes invisible.

In this size works, the only by-products are coke and tar; ammonia liquor is allowed to go into the tar well with tar. On the amount of residuals saved, and the market for same, depends the cost of gas and the earnings of the company. In locations where soft coal for domestic purposes costs, say, $4.50 per ton, it is not unreasonable to expect $7 per ton net for coke. Three cents per gallon for tar is a fair price. Without going into detail figures one can readily see what an important item the " residuals saved " is.

Coke is generally placed in the open, and where there is a

demand for crushed coke for domestic use, a shed is built to keep it out of the wet. A wagon scale must be provided for weighing all coke sold.

Tar from the well is pumped into barrels to be sold, and several full barrels should be on hand at all times.

The yard man usually attends to the weighing of coke and pumping of tar, and delivers coke, tar and other material, which is done only on a written order from the office.

In the meter room is located the works office, in which is kept a record book, showing the station meter, as well as the holder readings at 6 A.M. and 6 P.M. This record also shows the amount of coal carbonized, coke made, used and saved, tar made, coke and tar sold, as well as the amount of coal received; giving such information as car number, etc., whereby coal bills can be checked up. From this record, or log, the monthly report is made up, which should show the amount of coal carbonized, coke saved, tar made. It should also show the station meter and holder readings on the first and last days of the month, whereby the amount of gas made and sent out from the works can be determined.

It should set forth the amount of coke and tar which was delivered from the works during the month, also the amount of the pay-roll properly distributed to the different items, whether it be for manufacture, distribution, office help or improvements.

In the operation of a gas works, there are times when a company is unfortunate enough (through a broken main or other circumstances, over which it has no control) to find itself with an empty gas holder, and in case this should happen in night-time, and the pressure become so low that the gas will not burn, the proper thing to do is to close the valve on the outlet of the holder, so that the gas will be completely shut off the town. This precaution will save a great deal of trouble, because we know there are some concerns and some people who burn all-night lights, and if the gas is not completely shut off the mains these lights will go out, and the moment a gain is made on the holder, the gas will begin to go through the burners, which may occasion the loss of lives and property; therefore, a standing rule should be maintained whereby, in case the holder becomes empty during the night-time, the valves on the outlet of the holder be closed and not opened until next day.

Distribution. In the distribution of gas there are certain items which have to be taken care of, such as repairs to mains and services, that is, stopping leaks, etc. Where a plant is located

in a northern latitude, this should be done during the summer.

Leaks along the gas mains are usually located by driving down a pointed bar over the main, and if there is a leak the gas will come up through the hole, and can be ignited. There are several gages made for testing through these holes, but an experienced street foreman will be able to tell by the smell how much of a leak it is. After a leak has been discovered, holes are bored in both directions away from the first hole bored, and through the one giving the strongest smell, or light, the location of the leak is determined. The stopping of the leak depends on the character of it, and the methods best adapted for stopping same are adopted.

In this branch, there should be a competent "all-round" fitter and a helper. He should attend to all repairs of both mains and services, pumping of drips, setting and removing of meters, and reading of meters. His duties are not laborious, but he can be kept busy with the many "little jobs." His hours are not very regular, as there are times when he works late, and as he is in and out at all times he should be a man in whom confidence can be placed.

He and his helper look over the "complaint book" every time they come into the office, and see to it that complaints of every character are taken care of. On leaving the office they generally tell where they are going, so that the office can 'phone them if necessary to have them tend some complaints before they return.

From the office storeroom all supplies, such as mantles, chimneys, stoves, etc., should be issued, and a proper system of stockkeeping instituted, whereby a record of the stock is kept, and this store and stock should be in the keeping of the assistant bookkeeper. A liberal supply of mantles, chimneys, stoves and repair parts should be carried in stock, as well as extra meters and connections. The company should also have a pipe-fitting shop, in which at least one man and helper should be kept busy, running services, setting stoves, piping houses, etc. These men can also lend a hand to set and remove meters.

A meter record book should be kept in which the meter should be entered and given a number; a tin tag, with the number, should be soldered on the meter, and the record should show just where and when that meter has been in use. By this record the company can tell at a glance where the meter is; if it has been destroyed by fire this should be noted in the

"remarks" column of this book. The importance of this record may be emphasized when I say that while in charge of the Butte Gas Company's plant, and during the first year of my incumbency, I found over forty meters which were in constant use for over three years through which the company was getting no revenue.

Watch the consumers' meters. They are the life-blood of the company.

Office and Office Help. A company should have a neat and clean office, centrally located, and one into which women could always come, and the help should be such as to afford courteous treatment at all times.

Generally, in a town of this size, the superintendent is a man possessing the ability to fill the place of manager as well as that of superintendent. He should be familiar with bookkeeping so as to be able to check up the books from time to time, and see that the trial balances are properly and correctly taken off each month. He is the man who is responsible to the directors for the physical as well as the financial conditions of the property.

A bookkeeper who is accurate will be in charge of the office, and a system of bookkeeping such as is universally used by gas companies, with the necessary books, blank bills, etc., should be at his disposal; and with the aid of an assistant, who would attend to the posting up of consumers' ledgers, etc., and assist with collections, the office force would be complete. The system of bookkeeping as well as payment of bills I recommend would be that known as "voucher" system, where the use of a journal is practically dispensed with and the amount of bookkeeping reduced to a minimum. The manager should be familiar with this system, so that he could examine the books from time to time, to see that everything is being correctly carried on in all branches. There should be no difference between the conduct of the business and the system practiced in a large city; or, in other words, bills should be paid promptly, and unless there is some reasonable excuse, bills should not be allowed to run from one month to the other. Collections should be close, and bad bills few. This applies not only to the sale of gas, but also to coke, tar and supplies, such as mantles, chimneys, etc.

In the office should be exhibited the different gas apparatus for sale, some of which should be connected for demonstration purposes, and the bookkeeper and his assistant should be familiar with the uses of these different apparatus, the amount of gas

each will consume per hour, and should be able at all times to intelligently inform prospective patrons just what to expect.

Revenue. In dealing with this subject, we will start in at the gas works, and with the item of coke. It has been shown that coke is a very important factor in the revenue of a gas plant.

The next item will be tar, for which there is quite a market, and as the use to which these by-products are put has already been mentioned it will be unnecessary to say anything further regarding same.

The larger the revenue derived from coke and tar, the less will be the cost of making the gas. At one time in the annals of the gas business many companies boasted of the fact that the revenue derived from the sale of coke and tar was equal to, if not slightly in excess of, the cost of coal and labor making the gas, so that the cost of gas in the holder was *nil.*

Having considered the physical and operating phases, let us now consider the financial phases and see what good a company can be to its stockholders.

Without going minutely into details, I will say that in a town of 30 000 people there should be one meter to every ten persons, which would make 3 000 meters, and these, with gas at $1.50 per 1 000 cu. ft., should average $30 per meter per annum, making a gross of $90 000. If a good gas coal can be had for $4.25 per ton in the shed, and coke sells for $7 per ton, and tar 3 cents per gallon, then the total expenses of the company, including all charges, should not exceed 60 per cent., which would leave a net revenue of $36 000 per year. The cost of a plant capable of making the amount of gas needed to supply a town of this size will be about $250 000. The net revenue will be nearly 15 per cent. on the investment.

Owing to the fact that I am called upon from time to time to examine the books of, and make reports on, public utilities corporations, it might be considered a breach of confidence should I give details of the cost of operation, etc., so that I will ask the reader not to think this information is withheld without proper cause.

The up-to-date gas company must adopt the aggressive methods of the electric companies, which in many places install lamps and make renewals free of cost. Most gas companies sit back and wait. Generally, they are not as progressive as the electric fellows; then the directors wonder why they are losing business to their competitors.

In a combined gas and electric-light plant, with gas at

$1.50 per 1 000 cu. ft., and electricity at 10 cents per kw., the company pushes the gas end for fuel and the electric end for light, for with electricity at ten cents per kw., gas (as used through a mantle burner) should bring $4.00 per 1 000 cu. ft. With this fact in mind one can readily see why the electric company can afford to give away lamps.

That electricity is more convenient, and safer for decorative, and even certain other kinds of illumination, and is also convenient for use on the table in a coffee percolator, toaster, or chafing dish there is no doubt; I do not, however, expect to see the gas company put out of business owing to the competition afforded by electricity.

I would like to say that as much of my livelihood is obtained from electrical as is from gas engineering, so that I am speaking as one who is unbiased.

To the gas company just starting in business I strongly recommend that provisions be made for sufficient capital to pay for and install gas stoves while the plant and piping system is being constructed, the stoves to be sold on small monthly payments. This enables the plant to be started on a dividend-paying basis from the first day that gas is turned into the mains.

Take, for instance, a western town of 12 000 people, in which a gas plant is about to be built. I know that 1 500 stoves can be placed on such a basis; say, however, that only one thousand stoves are put out, these will earn $24 000 per annum, gross, and after paying all expenses, including 6 per cent. interest, and 4 per cent. sinking fund, will leave $9 600 (from these stoves alone) to be used in making dividends, which will be nearly 10 per cent. on the cost of the plant. This is not, however, the total gross revenue, because there should be at least three or four hundred consumers, such as restaurants, laundries, etc., which will use gas for illumination and other purposes.

With several of these towns operated under one central management the revenue will be considerable, and to the man who says that "a gas plant in a small town will not pay," I will come back by saying that if he will build new gas plants in small towns and operate in an up-to-date manner, he will find that he is away ahead of the fellow who purchased an old run-down plant in a large city, paying a big price for same and furnishing capital to rehabilitate and operate it.

In presenting this subject I have endeavored to set forth both sides of the question, and if I have been over zealous in telling the faults, or what I may call slothfulness, of some gas

companies, I trust that my criticisms will be taken kindly. They are not intended to depreciate companies, nor yet the gas industry, because it is not in the province of man to do the latter. The industry is too old, and when we look around and see what is being done, it would be foolhardiness in any one to attempt to deceive the public by saying that the gas industry was not a paying one.

It may be asked, Why did you select a city of 30 000? Is this the smallest number which should be served? I will say that my reason for selecting this size plant is for the sake of convenience, for had I taken as an example a works of larger size I should have been compelled to go into many branches (not included in this article), which would make too lengthy a paper and take up too much space.

There are no cities in this country of 30 000, and very few of over 10 000 (with the exception of certain of the Southern states), which are not supplied with gas, and the following statistics will prove interesting.

There are 967 towns in the United States which use artificial gas.

In the states east of Ohio, there are 410 towns; in the Southern states, 99, and in the Western states, 458, which are analyzed as follows:

Towns of 1 000 and over	71	Towns of 65 000 and over....	4
,, ,, 1 500 ,, ,, ...	11	,, ,, 70 000 ,, ,, ...	7
,, ,, 2 000 ,, ,, ...	30	,, ,, 75 000 ,, ,, ...	10
,, ,, 3 000 ,, ,, ...	43	,, ,, 80 000 ,, ,, ...	2
,, ,, 4 000 ,, ,, ...	32	,, ,, 85 000 ,, ,, ...	1
,, ,, 5 000 ,, ,, ...	76	,, ,, 90 000 ,, ,, ...	7
,, ,, 6 000 ,, ,, ...	52	,, ,, 95 000 ,, ,, ...	1
,, ,, 7 000 ,, ,, ...	46	,, ,, 100 000 ,, ,, ...	17
,, ,, 8 000 ,, ,, ...	52	,, ,, 125 000 ,, ,, ...	7
,, ,, 9 000 ,, ,, ...	16	,, ,, 150 000 ,, ,, ...	9
,, ,, 10 000 ,, ,, ...	156	,, ,, 200 000 ,, ,, ...	8
,, ,, 15 000 ,, ,, ...	89	,, ,, 250 000 ,, ,, ...	5
,, ,, 20 000 ,, ,, ...	63	,, ,, 300 000 ,, ,, ...	4
,, ,, 25 000 ,, ,, ...	43	,, ,, 350 000 ,, ,, ...	2
,, ,, 30 000 ,, ,, ...	31	,, ,, 400 000 ,, ,, ...	2
,, ,, 35 000 ,, ,, ...	18	,, ,, 450 000 ,, ,, ...	2
,, ,, 40 000 ,, ,, ...	17	,, ,, 500 000 ,, ,, ...	2
,, ,, 45 000 ,, ,, ...	9	,, ,, 550 000 ,, ,, ...	2
,, ,, 50 000 ,, ,, ...	16	,, ,, 1 600 000 ,, ,, ...	1
,, ,, 55 000 ,, ,, ...	8	,, ,, 2 000 000 ,, ,, ...	1
,, ,, 60 000 ,, ,, ...	6	,, ,, 5 000 000 ,, ,, ...	1

Only 24 of these are municipal plants, and one is at West

Point, owned by the federal government. Of the total number, 567 are plants doing gas business only, and 391, or 42 per cent. of the whole, are combined gas and electric-light plants.

It may be well to show the number of towns in the different states, so that the reader may judge for himself whether or not the territory is properly covered. It must, however, be borne in mind that this refers only to towns with artificial gas plants. There are a number of small towns supplied from one gas plant, which towns are not shown in the list.

The following is a list carefully prepared from data contained in Brown's Gas Directory for 1910:

Alabama	10	Louisiana	3	North Dakota	4
Arizona	6	Maine	10	Ohio	33
Arkansas	5	Maryland	14	Oklahoma	4
California	67	Massachusetts	64	Oregon	6
Colorado	9	Michigan	54	Pennsylvania	87
Connecticut	12	Minnesota	18	Rhode Island	6
Delaware	5	Mississippi	8	South Carolina	4
Dist. Columbia	2	Missouri	25	South Dakota	10
Florida	12	Montana	4	Tennessee	6
Georgia	12	Nebraska	16	Texas	19
Idaho	2	Nevada	3	Utah	2
Illinois	62	New Hampshire	12	Vermont	9
Indiana	44	New Jersey	52	Virginia	14
Iowa	44	New Mexico	2	Washington	10
Kansas	4	New York	104	West Virginia	4
Kentucky	14	North Carolina	12	Wisconsin	40

In this country there are 35 manufacturers of gas appliances, 17 of which are making coal stoves in addition to gas appliances. Eight large and 21 small manufactories are located in the West; 3 large and 4 small plants are located in the East.

The following table shows the distribution of ranges using artificial gas in the United States:

In use in twelve states east of Ohio and north of Virginia	1 387 100
In Southern states	92 248
In states west of Pennsylvania	1 398 229
Total number of artificial gas ranges	2 877 577

In addition to which it is estimated that there are 500 000 water heaters using manufactured gas.

In the sections where natural gas is found there is a very large sale of gas appliances, owing to the cheapness of gas. These appliances are especially made for the natural gas trade, and in

the seventeen natural gas states there are in use 4 140 840 gas appliances, of which 1 308 282 are ranges. In Pennsylvania, New York and West Virginia, there are 1 276 607 gas appliances in use; while in Ohio alone there are 1 338 642 such appliances.

The total number of ranges (natural and artificial) made yearly in the United States is 415 000. The bulk of the manufacturing is done in the Middle West, the principal points being Detroit, Mich.; Chicago and Rockford, Ill.; and Hamilton, Ohio.

In certain locations towns of 3 000 can be profitably served, as is proven by the fact that 43 towns of this size enjoy gas service. Conditions, however, must be studied, and if several of these towns, say from 3 000 to 7 000 each, in the rapidly growing West, were taken under one management, financed right, built right, and operated right, the syndicate owning and operating them would make more money than it could out of many an eastern town the population of which equals the aggregate of the several small western towns. In many places a group of small towns, say from one thousand to five thousand people each, are supplied by means of high-pressure distribution from one central plant, whereby the population per plant is increased, and a paying investment is the result of this combination.

I have often heard the capitalist say that " there is no money in a gas plant located in a small town." Not long ago I was told by a financier that " he would not consider a gas plant in a town under 20 000." He is wrong; and I will refer to the statistics herein given, which show that 429 plants in operation in the United States are in towns of under 10 000 people; 156 plants in towns under 15 000; 89 plants in towns under 20 000; aggregating 674 plants, or 70 per cent. of the number of towns supplied with gas. If there is " no money to be made in a small town," how is it that these concerns keep going, and each year the number is being added to?

Unless the investor makes up his mind *to go into small towns* and build and operate gas plants, the gas industry *must stop just where it is,* because there are no more large towns in which to do business. The great trouble is, the average gas company is not progressive, and they attempt to run business in the small town in the same manner as it is done in the large city, where they get business because they cannot help it; then, when they fail to interest and educate the people to the use of gas, they tell you that the small town won't pay.

Further advice is, don't buy " run-down " plants and spend

a lot of money rehabilitating them. There is a reason for their being "run down." Many times it is poor management, but in most cases it is due to the heavy burden — alias, high financing — which the plant has to carry.

I know of a plant which was built by a friend of mine at a cost of $115 000; having issued $65 000 of bonds and $50 000 of preferred stock to build same. He sold his company a little while ago, and now the plant has a debt of $350 000 of bonds, besides $750 000 of common and $250 000 of preferred stock. How can any one expect a plant in a town of 30 000 people to carry this load?

In purchasing an old plant a large price is paid for the franchise and the going business. Conditions are not generally properly studied, and contingencies arise, which "knock the bottom" out of everything. The plant has to be "scrapped," leaky mains must be attended to, capital has to be furnished for extensions and getting new business, which makes a load greater than the earnings of a plant can carry.

Among my varied experience I have in mind a town of 11 000 people in Ohio. A company paid $110 000 for the gas and electric-light plants, including franchise and going business. After this purchase was made I was called in for the purpose of designing and building a modern electric-light and gas plant. Upon being told the amount which was paid for the plant I said to the owners that the purchase price was too large, but they were satisfied. I also called their attention to the fact that they were dangerously close to the natural gas field, and that there would be trouble some day. To make a long story short, it was necessary to "scrap" the electric-light plant, for which the company paid $30 000, $2 700 being received for the old steam and electric apparatus. The gas plant for which they paid $25 000 was also "scrapped," less than $100 being received for the old iron.

Having in mind the fact that natural gas would be some day piped into the town, I designed and built a gas engine driven electric plant, using coal gas in the engines, but knowing that at such time that natural gas was piped into the town arrangements could be made whereby these engines could be operated by natural gas instead of coal gas. Inside of two and one-half years natural gas was piped into the town. The local company could not make a deal to handle same, and the coal-gas plant was shut down, and this being the largest revenue producer, the company went into the receiver's hands. A local party bought it out at court sale for $15 000, and is to-day operating

the gas engines in the electric-light plant by using natural gas. In this case, a proper study of the natural-gas situation by the company, or its advisory engineer, at the time they were about to purchase the plant, was not made. The failure was not the fault of the small town.

So much for your old plant. It is a mistaken idea for capital to think that a going concern is the only one in which to invest. When it comes to the gas industry one is taking no chances if he gets hold of the proper party to look up the field, study the local conditions and give proper advice.

"High financing," not "small towns," is principally the cause of failure.

Finis. In conclusion, I will say that the gas engineer (especially the consulting engineer) must be willing at a moment's notice to pack his grip, board a railroad train and "hie" to some point for the purpose of investigating a plant the physical property or bond issue of which is for sale, and when on the ground he must be able to examine the company's books to determine whether or not the statements submitted to the bank or bond house are correct. He must inspect the property so as to place a value on the physical assets as well as the franchise and going business, and last, but not least, he must be able to study conditions whereby the future growth of the company's business can be assured.

After gathering these data, he must put them in tangible form; in other words, he must make up a comprehensive report, worded in such a manner that the investor, who has not the time to go on the ground, or knowledge to investigate the business, can readily understand and see in his mind's eye the kind of a proposition he is about to invest his money in. To enable the engineer to do this the investor must be willing to give him enough time in which to make the investigation and report. Don't hurry him. Engineers are like other men; they are honest, but they are also human. A quart measure, when full, can hold no more; if it takes a month to make a proper study of any proposition, don't ask the engineer to do it in a week.

In many instances engineers are limited as to time, as well as to the amount which a report should cost, and there are even times when investors ask an engineer to go out and make a report, and, "if the project is all right, it will be considered and financed." What a temptation! Tell a man if his report is favorable he will be paid. Just think of it! There are not many men

who can stand such a temptation, and a favorable, instead of an adverse, report is often the result; then disaster.

Take time to select your engineer; don't let him feel that he is in the capacity of a "hired man," but on the contrary let him know that you have confidence in him, and that the confidence is so great that you are willing to invest on his say so. Pay him well for his services for making a report and advising you regarding your investments, whether the advice (after due investigation) is favorable or otherwise. An adverse report may save you thousands of dollars.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1911, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF PAPER, "METHODS AND COSTS OF CONSTRUCTION OF THE SLOW SAND PURIFICATION WORKS FOR THE NEW SPRINGFIELD, MASS., WATER SUPPLY."

(VOLUME XLV, PAGE 189, DECEMBER, 1910.)

MESSRS. MORRIS KNOWLES* AND FREDERICK E. FIELD.† — The author of this paper should receive the congratulations and thanks of engineers and contractors, who are interested in either estimating the cost of, or in constructing, such works, as it is infrequent that a contractor, even if he has systematically taken and recorded the cost of work for his own use, is sufficiently broadminded to publish such records for the benefit of others. The paper should be especially commended:

First, for the definiteness of the description of conditions under which the work was performed and the methods by which it was accomplished.

Second, for the careful and systematic tabulating of the items of cost in such detail as to make it possible — due, no doubt, to the methods of daily cost keeping — to compare them with costs of work elswhere.

Third, for the frankness with which the author comments upon the various figures of cost, even to acknowledging and explaining where errors of judgment, either as to plant employed or methods followed, entered into the work and resulted in increased cost and subsequent loss of profit to the contractor.

METHODS OF COST KEEPING.

The method of cost keeping which the author employed on this work, and which gave such satisfactory results, is practically the same system which was adopted and used by the engineering force of the Bureau of Filtration of Pittsburgh, Pa., during the entire period of construction of the Pittsburgh Filtration Works, from 1905 to 1910 inclusive, costing about $6 500 000.

On the Pittsburgh work there was what was known as the "Central Force Account Division," with a man in charge, under whom were both office and field clerks. Prior to the beginning

* Chief Engineer, Bureau of Filtration, Pittsburgh, Pa.

† Principal Division Engineer, Bureau of Filtration, Pittsburgh, Pa.

of work on any contract, a "Distribution of Account" sheet was made out, in which, similar to the method employed by the author, the work on any contract was first noted by its "Item," then subdivided under lettered "Sections" and numbered "Subsections," to indicate the class of work and the detailed cost of all plant materials and labor chargeable to that particular item. With this as a basis, other printed forms were adopted, upon which the daily, monthly and final accounts were made out, either in detail or in summarized form, as desired. (See sample forms, under Figs. 1, 2, 2A, 3 and 4.)

The field force account clerks, on their bi-daily, or more frequent, trips about the work, obtained records of the number and wages of men employed on the various subdivisions of the work, the plant and material used, the materials and supplies received, etc. Furthermore, each inspector on the work was required to keep a daily diary, in which was recorded in detail the force, labor and materials used upon the work for which he

Form V No 15

Contract. 11 Sec C Subsec 5 Item 14 Date. September 4 1909.

Description Concrete in Vaulting Signature Jos Lees.

Work	Progress	Material Used	Cost	Plant and Tools	Cost	Class of Labor	Rate	Time	Total Time
Delivering materials (+ transporting	165.42 cu yds	861 sacks cem.		Haines Mixer Cable way	33.87				
Placing	"					Foreman	30	14	
						Laborer	15	56	
						"	13½	70	
						Boy	10	14	
Finishing	"					Foreman	25	7	
						Finishers	20	70	

FIG. 1.

was responsible, together with the quantity of work done on each subdivision of the work during that day. These diaries were handed in each day to the "Central Force Account Division," which was thus enabled, by the data obtained by its own clerks and the regular inspectors, to record and summarize the costs of the work.

At the end of each month, the quantities of work done, as estimated by the force account clerks and the inspectors, were checked by the engineer's monthly estimate of quantities, thus obviating error and balancing the cost of work to date. It was not, however, practical to balance monthly the large items of general expense and plant charges, such as staff charges of the administrative force, office expense, plant charges of cable-

Contract No. 11, Sec C, Sub-Sec 3, Item 14, Month of September, 1909

CITY OF PITTSBURGH, BUREAU OF FILTRATION. MONTHLY SUMMARY OF FORCE ACCOUNTS

Description Concrete in vaulting

TOTAL TIME DURING EACH DAY OF MONTH. (TIME OF MEN HIRED BY DAY, IN DAYS, BY HOUR, IN HOURS)

Work	Class of Labor	Rate	Days 1–31	Total Time	Rate	Amount	Material	Plant Depr'tion	Grand Total	Work Done	Cost Per Unit
Mixing and placing Concrete			[illegible]			319.92					.2[illegible]
						319.92					
	Cu. Yds.		[illegible]	1434.[illegible]							
	Sacks Cement		1 7 638 … 861 220 1124 3[illegible] 94 … 3 … 62 … 302 375 330 317 437 370 468 … 483 … 443 427	8014							
Placing	Foreman	30	2 9 … 14 14 14 8 2 … 2 … 10 10 14 14 14 7 9 … 10 … 8 10	168	30	50.40					
	Laborer		3 43 … 36 10 36 32 … 16 … 85 141 126 135 135 66½ 85½ … 95 … 72 77	1250	15	187.50					
	"		3 26 42 … 70 22 70 40 10 … 5 … 10	288	13½	38.88					
	Boy	10	2 … 14 2 7 4 1 … 1 … 5 8 7 7 7 3½ 4½ … 5 … 4 5	87	.10	8.70					
	Foreman	25	1	1	25	.25					
	Derrickman	25	5 5 7 7 7 3½ 4½ … 5 … 4 5	56	25	14.00					
						259.73					2[illegible]
Finishing	Foreman	25	2 … 2 … 7 4 1 … 5 5 4½ … 3 4	49½	25	12.38					
	Finisher	20	12 38 … 70 10 49 24 6 … 10 10 3 … 15 15 30 49 49 49 20 31½ … 35 20 32 28	651½	20	130.30					
	Laborer	13½	8								
						142.68					0[illegible]
Plant	Labor	13½	10	10	13½	1.35					
						1.35					.00[illegible]
						763.68	2491.26	1312.93	4567.87	.480	3[illegible]
						5'6	683	8[illegible]			

FIG. 2.

ways, derricks, shops, interest charges, etc., and these were apportioned at the end of the work.

Fig. 1 illustrates the usual 5-in. by 8-in. "Time Card," as filled out by the "field-force-account-clerk," with data obtained personally and from the regular inspectors' diaries.

Fig. 2 gives a typical "Monthly Summary of Force Accounts" for one item of the work (i. e., concrete in vaulting). This illustrates how the daily record of labor and material costs, obtained from the 5-in. by 8-in. cards noted above was assembled under the important subdivision at the end of each month.

Fig. 2A gives the method of computing the "General Charges" and "Material Costs," which are added to the data given on summary in Fig. 2.

FORM 73 MATERIAL COSTS FORCE ACCOUNTS, MONTH OF September 1909

CONTRACT NO 11 SEC. C SUB SEC. 5 ITEM 14

DESCRIPTION	QUANTITY	RATE	AMOUNT			REMARKS
		%				
Staff	9620"	1.976	190	09	0.1284	
Repairs	"	1.112	106	97	0.0722	
Coal	"	0.284	27	32	0.0184	
Bonds		3.287	316	21	0.2136	
Plant		3.698	355	75	0.2404	
Gen Concrete		2.316	222	80	0.1505	
Dressing Lumber		0.975	93	79	0.0633	
		13.648	1312	53	0.8868	
Cement	8074	.25	2018	25		
Sand Cu yds	769.6	28	215	49		
Gravel "	1287.6	20	257	52		
			2491	26		

FIG. 2A.

Fig. 3 shows the grouping of the data obtained from the "Monthly Summary of Force Account" sheet, shown in Fig. 2, for the "Semi-Annual Summary of Force Accounts."

Note that the "Unit Cost" of the concrete in vaulting from this sheet agrees with the "Unit Cost" given in table No. 1, after deducting the cost of "Forms," given in a footnote.

Fig. 4 shows the assembling of the distributed "Monthly Estimate of the Engineers" with the "Unit Cost," obtained from the "Force Account Records."

The results of this systematic method of cost keeping were of value in several ways.

First. The engineering force was enabled to have daily and monthly records of the cost of the work, in as much or as

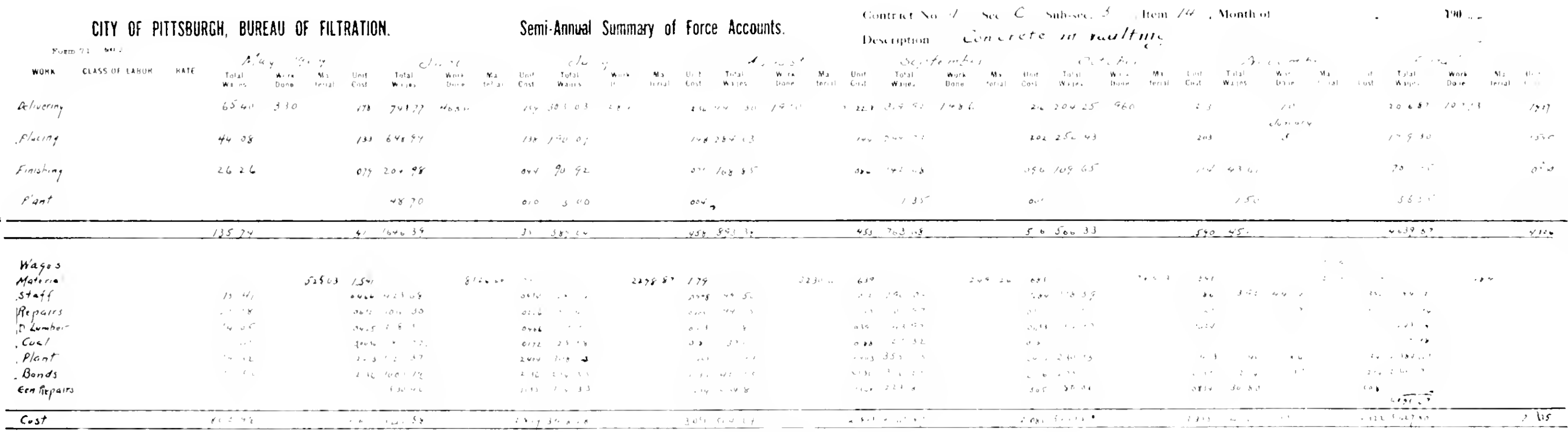

CITY OF PITTSBURGH, BUREAU OF FILTRATION.
Semi-Annual Summary of Force Accounts.
Contract No. 1 Sec. C Sub-sec. 5 Item 14, Month of 190
Description Concrete in vaulting
Form 71
WORK
CLASS OF LABOR
RATE
May
June
July
August
September
October
November
Total Wages
Work Done
Material
Unit Cost
Delivering 65 40 330 178 74 77 151 303 03 20 4 25 960 20 6 87
Placing 44 08 133 64 84 202 25 43 203 17 9 30
Finishing 26 26 079 20 98 044 90 92 108 85 056 109 65
Plant 48 70 010 5 00 135 150
135 74 455 763 08 5 6 566 33 590 45
Wages
Material 52503 154 179 659
Staff
Repairs
D Lumber
Coal
Plant
Bonds
Gen Repairs
Cost

Fig. 3.

Form 11 11 6

CITY OF PITTSBURGH, BUREAU OF FILTRATION. Distribution of "Monthly Estimate" and Force Account for Contract No. 11, Month ending *September 30 1909*. Sheet 2

No. of Line	Sec	Description	Sub Sec	Description	Item	Description	Specifications Page	Specifications Sec	Previous Quantities	Cur. Quantities	Total Quantities	Calc Book No	Calc Book Page	Distribution of Estimate: Prices	Previous Amounts	Current Amounts	Total Amounts	Distribution by Force Account: Previous Amounts	Current Amounts	Cost per unit for Current Month	Total Amounts	Average cost per unit to date
	C	Filter Structures Cont'd		Vaulting	11	Concrete in Vaulting	123	107	8270	1480	9750			$ 6 50	53755	9620	63375	23684 40	4657.87	3.086	28252.27	
					12	Ventilator frames and covers	173	315	30	15	45			15 00	450	225	675	223 60	114.71	7.647	338 31	
					15	Arch centering	121	113	347500	54500	402000			13	45175	7085	52260	16581.97	1351.79	0 0248	17933 76	
			6	Main Collector	16	Rein. Concrete, Conduits and drains	125	118	130	136	266			8 10	1053	1101.60	2154 60	887 54	567 56	4 173	1455 10	
					23	Steel Rein	132	150	2880	1620	4500			04	115 20	64 80	180	109 05	43 85	.0271	152 90	
					48	Misc. W. I. and Steel								05								
			7	Filter Doors	38	13-2 x 5-11 Sluice Gates	160	259	96	2	98			800 00	7680.	160	7840	6905 54	166.95	83475	7072 49	
			8	Track System	58	Tee Rails	185	369	415	163	578			50 00	20750	8150	28900	14086.34	6130.22	37 608	20216 56	
					59	Brackets, hangers, gaskets etc	187	378	61000	17000	78000			06	3660	1020	4680	2826.90	925 04	.054	3751.94	
					45	Pipes, bolts etc.	168	295	48000	12500	60500			05	2400	625	3025	2114.44	555 87	.0443	2670 31	
					49	Vault fasteners	171	304	10950	1050	12000			05	547.50	52 50	600	371 81	36 20	.0343	408 06	
			9	Inlet Chamber	18	Ladder steps, Inlet platform, Stop plank angles	168	296						05								
					49	Vault fasteners Doors at Inlet	171	304	1150	0	1150			05	57 50	0	57 50	44 54			44 54	
	D	Gallery Structures	1	Floors	11	Concrete in floors	119	93	1490	0	1490			6 50	9685	0	9685	4620 68			4620.68	
					21	Gallery drain	134	156						15 00								
					25	Machine Pit	136	168	25	0	25			1 25	31 25		31 25	15.05			15 05	
			3	Piers	11	Concrete in piers	122	101	14	6	20			7 50	105.	45	150.	342 37	33 18	5 53	375 55	
			2	Platform	17	Misc. Rein. Concrete	126	121	360	10	370			12 50	4500.	125	4625	3467 48	84 46	8 446	3551 94	
					23	Rein. Metal	132	150	30400					04	1216	16	1232	771 42	8 ..	.00406	790 61	
										Sheet Total					151 180 45	28289.90	179470 35	72033 68	4596 38		76630 06	
										Bro't Forward					221 212.60	24172 ..	245384 50	108843 03	10 789 40		119632 43	
										Total					372 393.05	52461 80	424854 85	180876 ..	25385 78		206 262 49	

FIG. 4.

little detail as desired, the current data not including "Genera Charges."

Second. A check was secured on such items of "Extra Work" as were executed by the contractor and paid for on the "cost plus a percentage method," claims for which were frequently not promptly made by the contractor.

Third. An official and permanent record of the cost of the work was obtained with suitable allowances for "General Expense."

Fourth. A valuable aid for estimating the cost of future work was thus placed at the disposal of all thus interested.

All these cost records were obtained by the engineering force alone, and without any assistance from the contractor, who was adverse to giving any information of this character. Notwithstanding the difficulties of obtaining the desired information under these conditions, a general check on the accuracy and correctness of the work was finally secured. Before the final settlement of the early filtration contracts, aggregating $5 500 000, an audit of the contractor's books was made, and in this way the stated actual cost of the work, indicated by the contractor's own records, was obtained by the engineering force. The differences in accounts were slight and occurred largely upon items other than labor, where the full details were naturally not known to the engineers. The differences are as follows.

On pay-roll:

Engineers' account, $\frac{6}{10}$ per cent. higher than contractor.

On materials, plant, subcontract work, etc.:

Engineers' account, $8\frac{3}{10}$ per cent. lower than contractor.

On total cost of work:

Engineers' account, $3\frac{5}{10}$ per cent. lower than contractor.

We have been especially interested in the statement that the "General Expense" amounted to 12.9 per cent. of the other costs of the work. The early filtration contracts at Pittsburgh, valued about $5 500 000, had a total general plant and administrative expense of about 19 per cent., of which 6.5 per cent. was for plant charges.

The item for grubbing is very instructive, for it may commonly be said that estimates for such work are usually too low. Much also depends upon the detailed character and extent of the work required. Some work under the observation of one of the writers was originally estimated to cost an average of $67 per acre; while present records, covering 145 acres out of a total of 390 to be done, show the actual cost to run about $120

per acre, including general expenses. This also includes cost of cutting and piling cord wood, about one fifth of the total cost, which in some few cases has amounted to 200 cords per acre. The work includes all cutting of roots, allowing trees to pull out stumps as they fall over, the blowing out of some old stumps left by previous timber work, and the grubbing out of all underbrush and roots.

Concrete Masonry.

In reviewing that part of the author's paper concerning concrete masonry, the writers have been especially interested in the plant used, the methods employed in doing the work, and the results and costs.

It may perhaps be granted that, at the Springfield Filtration Plant, the derrick system of handling the work, all other conditions considered, may have been the most economical, — due to the lesser first cost and the possibility of later disposing of the derricks advantageously. But the cableway system has been found advantageous on work of approximately the same size, and especially efficient on larger works of construction, where the first cost of plant is secondary to rapidity of progress, adaptability for many classes of work, non-interference with progress of dissociated items of the work, and simplicity of operation.

We do not agree with the author's statement on page 33, "It would not be practical to utilize the cableway for this purpose," viz., in setting or removing forms or transferring them from one filter to another. Our experience and knowledge of the filtration work at Philadelphia, Washington, D. C., and especially at Pittsburgh, indicates that the cableway is most exceptionally adapted for economical handling of forms; in fact, in the Pittsburgh work, forms were seldom handled in any other manner. It would be interesting to know whether the erecting of the hoisting engine and the subsequent operation of it upon the "green" or recently placed concrete in the filter roofs was not taking more than a reasonable risk toward developing cracks in the roof, even if not endangering the strength of the vaulting, due to eccentric loading or vibration.

The author states, on page 34, "Two derricks could handle the concrete as fast as a single cable could"; and on page 33 gives "125 to 150 cu. yd. as a large day's work." On the Pittsburg work, one cableway, on Contract No. 2, Filtered Water Reservoir, with a span of about 300 ft. and a distance of about

1 000 ft. from the mixer, placed 289 cu. yd. of concrete in a ten-hour day. On Contract No. 11, Ten Slow Sand Covered Filters, a cableway with 500 ft. span and a distance of over 1 000 ft. from the mixer, placed 432 cu. yd. of concrete in a ten-hour day. On this later contract, the single cableway placed 31 200 cu. yd. of concrete from April to October, 1909, both inclusive; or an average of 180 cu. yd. per day, based on 25 working days per month.

Pittsburgh Filters, Contract No. 11.

As we shall refer to this latter contract in comparing cost items, a brief description of this work may be of interest; it is more nearly comparable to the Springfield work in size and quantities than the work under Contract No. 1.

Contract No. 11 comprised 10 one-acre, slow-sand-covered filters, arranged in two rows of 5 filters, between which is a covered operating gallery.

The north wall of the filters is parallel to and about 50 ft. from the center line of the south bank of a large sedimentation basin. The east wall is within 50 ft. of a row of large trees bordering a large private estate. The west wall at one point comes within 25 ft. of a macadam road open to travel. The south wall extends, for a considerable length, at a distance from 25 to 50 ft. from the edge of an important and much traveled road, upon which electric cars pass at intervals.

South of this road, and parallel to it, there are the four tracks of the Western Pennsylvania Railroad, and about 500 ft. south of this is the bank of the Allegheny River, from the bed of which all sand and gravel for concrete and filter material were obtained. It is evident that the contractor was considerably cramped in his operations; in fact, it was necessary for him to place one line of cableway tracks considerably within the outside line of the south wall of the filters.

All concrete materials were brought to the receiving bins of a concrete mixer, of the Hains type, located on the river bank; there mixed and transported on flat cars, by dinkey engine haulage, through a subway beneath the Western Pennsylvania tracks, to a point where the buckets of mixed concrete could be lifted from the cars by the cableway. Three and one-half cu. yd. hopper concrete buckets were used, and it was in a large measure due to this type of bucket that such excellent progress was made.

Filter Material.

The author evidently experienced the usual difficulties met with by contractors in furnishing filter material, although in his case the local conditions were apparently especially severe. Similar difficulties of experimental trying-out methods and arrangements and large waste of original product are to be expected and should be planned for. A brief description of the plant and method employed by the contractor for furnishing filter sand and gravel for the Contract No. 11, Pittsburgh, is given, to illustrate this one feature of the work at Pittsburgh.

The specified requirements for filter sand and gravel for the Pittsburgh work did not differ materially from those at Springfield. The mixed sand and gravel, brought up from the bed of the river by the bucket conveyor, of the usual type of Ohio River ladder-sand-digger, was first thrown upon grate bars, spaced 5 in. apart, which removed all large stones. At this point a 4-in. stream of water, from a pulsometer pump, having a capacity of 420 gal. per minute, was played upon the material, washing it into a cylindrical screening tube, $3\frac{1}{2}$ ft. in diameter. Through the center of this tube, which was revolved at a rate of 14 revolutions per minute, there was a 4-in. perforated pipe, supplied with water under 35 lb. pressure, which furnishes the second and final washing of the gravel on the dredge.

The first section of this screen was 4.50 ft. long and had $\frac{3}{16}$-in. mesh, which removed the No. 4 gravel and sand. Outside of this screen there was a screen, with $\frac{1}{8}$-in. mesh, which separated the No. 4 gravel from the sand. The No. 4 or finest gravel was carried by a belt conveyor to the rear of the boat, where it was dropped into wheelbarrows and thus loaded into a barge.

The sand was carried by a chute to the sand-washing tank, consisting of a box about 6 ft. square and 5 to 6 ft. deep, having a false bottom of perforated plate, supported about 12 in. above the bottom of the tank. Water pumped into this lower compartment passed up through the perforated plate and the sand above and overflowed a waste weir at the top. The upward pressure and velocity of the water not only washed out all dirt and fine material, but also kept the sand in suspension and uniformly varying from coarse sand at the bottom to fine sand at the top. By the opening of gates in the side of the tank, sand of the required size and cleanliness was removed and conveyed by chute and thus loaded into a barge alongside the digger.

The second section of the main screen was 4.50 ft. long and consisted of punched plate with 1.50 in. square holes. This removed the mixed No. 2 and 3 gravel, which was loaded directly into a barge on the right side of the boat. The third and last section of the main screen was 3 ft. long, of punched plate with 3 in. square holes. This removed the No. 1 gravel, which was loaded into a barge by means of a belt conveyor. All material not previously removed passed out the end of the screening tube and was wasted.

The capacity of the dredge as equipped was four barges of sand and seven barges of gravel, or a total of 1 000 cu. yd. in 24 hr., which, however, varied somewhat with the material found in the bed of the stream. The loaded barges were then towed to the dock near Ross Pumping Station and unloaded into the receiving bins, as already described, and previously used for concreting materials.

Here the No. 1 gravel was run through a 3.50 ft. screen, 9 ft. long, with 1.50 in. mesh, which was revolved at 18 turns per minute, and in this way dirt and fine material were removed. The mixture of No. 2 and 3 gravel was treated in similar manner and then separated by passage through a similar screen with ½-in. mesh, being washed by means of a 1-in. perforated pipe within the screen. After these processes were completed, the different gravels dropped into the distributing bins below. As the No. 1, 2 and 3 gravel was removed from the distributing bins into the cars by means of chutes, it passed over fixed inclined screens and there received its final washing before being placed in the filters. The No. 4 gravel and the filter sand were not washed or screened after leaving the boat.

The screening of material to obtain any particular size of gravel is dependent on, —

The character of the raw material.

The dimensions of the screen openings, and particularly whether wire mesh or punched plate with square or round holes is used.

The length of the several screens.

The speed or number of revolutions of the screen tube.

The amount and pressure of water used for washing.

Considerable experimental work along these lines should be expected before satisfactory results are obtained.

The prepared filter material was transported in hopper cars, pulled by an electric locomotive, to the filters, where it was dropped through openings in the roof into special steel

TABLE 1.

Comparative Costs, Springfield and Pittsburgh (Contract 11) Filtration Works.

Class of Work.	Concrete Floors.		Concrete Walls.		Concrete Piers.		Concrete Vaulting.		Filter Materials.		
Location.	Springfield.	Pittsburgh Cont. 11.	Springfield.	Pittsburgh Cont. 11.	Springfield.	Pittsburgh Cont. 11.	Springfield.	Pittsburgh Cont. 11.	Springfield.	Pittsburgh Cont. 11.	
Quantity, cubic yards	3 933	10 540	2 481	2 892	708	1 543	3 673	10 773	*20 860	12 272	9 103
Unit cost	$5.35	$2.91	$6.45	$4.09	$9.29	$6.37	$6.87	$4.68	$2.05	Sand. (A) $0.97	Gravel. (B) $1.12
General expense	0.62	(a) 0.47	0.74	(a) 0.55	1.06	(a) 0.56	0.78	(a) 0.82	0.23	0.11	0.12
Plant charge	0.89	0.22	0.89	0.22	0.89	0.28	0.89	0.39	0.24	0.14	0.17
Concrete materials	2.87	(b) 1.63	2.87	(b) 1.83	2.87	(b) 3.34	2.87	(b) 2.30	.....	......	......
Forms, labor and materials	0.22	......	1.30	......	3.77	......	1.76	(d)	.....	......	......
Concrete, mixing and placing	0.75	(c) 0.59	0.65	(c) 1.49	0.70	(c) 2.19	0.57	(c) 1.17	.....	......	......
Expense at pit	....	......	....	......	....	......	....	......	0.33	(e) 0.49	(e) 0.54
Teaming to screens	....	......	....	......	....	......	....	......	0.77	......	......
Screening and washing	....	......	....	......	....	......	....	......	0.23	(f) 0.23	(f) 0.29
Placing in filters	....	......	....	......	....	......	....	......	0.25	......	......

* Includes both sand and gravel.

Note: (a) Includes estimated payment on bonds. (b) Includes materials for forms. (c) Includes labor for forms. (d) Forms for filter roof cost $1.759 per cubic yard of concrete at Springfield = $0.045 per square foot of roof. Forms for filter roof cost $1.743 per cubic yard of concrete at Pittsburgh = $0.043 per square foot of roof. (e) Material cost, including wages, etc., on dredge boat. (f) Wage cost, hauling and placing in filters. (A) Cost based on two fifths of total quantity of sand to be furnished under contract. (B) Cost based on three fifths of total quantity of gravel to be furnished under contract.

cars, running upon the permanent track system in the filters, and was thus distributed where desired.

Five months' records show that 14 550 cu. yd. of gravel and 23 670 cu. yd. of sand, or a total of 38 220 cu. yd. of filter material, was prepared and placed. This, on the basis of 25 actual working days per month, gives an average output of 305 cu. yd. per day. At times, the contractor worked an additional night gang, and thus we have no figures to compare with the ten-hour a day output at the Springfield plant.

Comparison of Unit Costs.

The table (page 141) is given to show in parallel columns the comparative cost of certain items of work at Pittsburgh, Contract No. 11, to the cost of similar work at Springfield.

Coöperation.

We would, in closing, urge a coöperative and harmonious relation between engineers and contractors, and a more usual practice of publishing the actual and detailed but inclusive cost of work in as clear and instructive a manner as has been done by the author. The statements as to the lack of theoretical best management being frequently present and, therefore, necessary to allow for are too often forgotten, much to the cause of low profits and lessened efficiency in the execution of work.

The relation between engineer and contractor is almost one of partnership, — one details and specifies the design and form of the work and the other constructs the work in accordance therewith. Whenever the engineer can simplify and standardize the design or the requirements under which the work will be accomplished, without detriment to the purpose and the ultimate successful operation of the work, he is aiding not only the contractor in his operations, but also bringing credit upon himself in a reduced cost of the work as a whole.

The author's remarks regarding the effect of the character of engineering and inspection upon the cost of work are timely; but, according to the writers' views, liberality of interpretation and application is frequently confounded with looseness and indefiniteness, which should never be the case. Public work often imposes certain exactness and arbitrariness of conduct to insure free and open competition and fairness to all, which private work does not compel, and firmness of position and intelligent interpretation, while it may make some particular piece of work cost more, will because of the established definite-

ness of procedure, do away, in the long run, with gambling upon uncertainties and unbalanced bidding, and thus produce fairer prices, even if not always lower ones, for standard good requirements for public work.

Mr. Frank S. Bailey. — It is a very regrettable occurrence when an engineer hands a "gold brick" to a contractor, as Mr. Lochridge states was done twice at Springfield, once in the matter of the test pits for determining the quality of the excavation for the filter site, and again in the test pits for filter sand.

Mr. Gow says, "Test pits had been sunk to grade by the city authorities at three points on a line running longitudinally of the site [of the filters]."

Mr. Lochridge says in regard to the same pits, "In our filter site test pits — I have forgotten the number, but they covered pretty generally the area which was to be excavated, 17 ft. deep at one end and running out to nothing at the other — we carefully avoided running into any bowlders. I don't know whether we had a divining rod or how we missed them, but at any rate these pits formed the basis of his [the contractor's] prices."

As the filter site has an area of over three acres, there was only one pit to an acre. The same result might be attained in some other field with many bowlders, that is, digging one test pit per acre and not striking a bowlder; but, if two or three or even four pits were put down, the theory of chances will show that the bowlders would have more difficulty in concealing themselves.

In regard to the test pits for filter sand, I do not find any statement as to the area of the field in which they were dug nor their number. Mr. Gow says, "Subsequently, however, when an attempt was made to secure sand from this locality, it was found to contain only about 1 500 cu. yd. of the 21 000 cu. yd. required, the original indication of quantity proving to have been misleading."

It is sufficiently evident that, as only 7 per cent. of the amount of sand expected was obtained from this locality, the preliminary examination of it was rather superficial.

Mr. Hazen says, "It seemed, under the circumstances, that it was fair to hold that the city had in effect guaranteed the sand deposits, and that it was equitable for the city to make the contractor good for the additional expense reasonably involved in the additional haul. This is a point on which discussion may be especially helpful."

If the city guaranteed the sand deposits, the engineers of the city were clearly at fault in not making a sufficiently thorough examination on which to base the guaranty.

DISCUSSION OF PAPER, "MANGANESE STEEL."

(VOLUME XLV, PAGE 175, NOVEMBER, 1910.)

MR. F. E. JOHNSON. — In my paper upon "Manganese Steel" (this JOURNAL, November, 1910) the statement is made that manganese steel is made in America by the Taylor Iron and Steel Company and by the Edgar Allen American Manganese Steel Company. It has come to my attention since writing the said paper that the Pennsylvania Steel Company, with works at Steelton, Pa., and at Sparrows Point, Md., are also large manufacturers of this material, and I hasten to make this correction accordingly.

MR. J. V. W. REYNDERS. — I have read with interest the paper on manganese steel, by F. E. Johnson, in the November, 1910, issue of the JOURNAL. While we appreciate that it is a difficult thing for any one in Mr. Johnson's position to be familiar with the statistics covering all makers of manganese steel in this country, it should be of interest to correct his statement that "we can almost confine the manufacture in the United States to two foundries." In total actual tonnage the production of the Pennsylvania Steel Company is no doubt greater than either of the foundries which he mentions, and there are also a number of other companies which are turning out good work in considerable quantities. No doubt there would be more if, as Mr. Johnson states, foundrymen had not "discovered that it was a very difficult metal to produce."

The tonnage of manganese steel going into track work is greater than that in any other single line, track work of this kind having superseded largely all others for street railway work and main line steam railroad work.

An interesting use of manganese steel which Mr. Johnson does not mention is made by certain safe manufacturers. Manganese steel safes cannot be drilled or broken into in any way without a vast expenditure of time and trouble, on account of the hardness and strength of the steel.

The Pennsylvania Steel Company has also introduced rolled manganese steel rails. These can be produced as straight and true to section as any rails and at a lower price than the cast manganese rails, which require a great deal of grinding at best. A considerable tonnage of these rolled rails is now in track and giving very satisfactory results, outlasting the life of ordinary Bessemer rails five to twenty fold.

OBITUARY.

George Leonard Vose.

PAST PRESIDENT, BOSTON SOCIETY OF CIVIL ENGINEERS.

GEORGE LEONARD VOSE, who was president of this society from 1884 to 1887, was born in Augusta, Me., April 19, 1831. He was educated at the high school of his native town and at schools in Salem, Mass. Desiring to become an engineer, he entered in 1848 the office of Samuel Nott, a prominent civil engineer practicing in Boston. At that time there were few schools of engineering in this country, probably the only ones being the Rennselaer Polytechnic Institute in Troy, the Lawrence Scientific School of Harvard, the Sheffield Scientific School of Yale, and the Engineering School of Union College. Mr. Vose remained in the office of Mr. Nott about a year, at the end of which time, feeling the need of further training in the science of his profession, he entered the Lawrence Scientific School at Harvard, where, however, he only remained one year. Those were the early days of railroad construction, when the lines which now constitute our trunk lines, or at least those subordinate companies afterward merged into our trunk lines, were being located and built. Leaving the Lawrence Scientific School, Mr. Vose was employed in various capacities upon the Kennebec & Portland Railroad in Maine, the Albany & Susquehanna Railroad in New York, the Providence, Warren & Bristol Railroad in Rhode Island, the Louisville & Nashville Railroad in Kentucky and Tennessee, the Stanstead, Shefford & Chambly Railroad in Vermont and Canada, the Northern Cross Railroad, from Quincy to Galesburg in Illinois, the Hannibal & St. Joseph Railroad in Missouri, and the Nova Scotia Railroad from Halifax to Windsor. In this work he gained a great variety of experience in the location and construction of railroads.

In 1860, however, he turned from this side of his profession, and thenceforward his life was to be devoted mainly to literary and educational work. For four years he was associate editor of the *American Railway Times*, published in Boston. In 1864 he moved to Salem, where he lived two years, and in 1866 he moved to Paris, Me., where he lived until 1872, engaged upon various engineering matters, and in the preparation of his hand-

book of railroad construction. He had published, in 1857, a "Handbook of Railroad Construction," containing 480 pages and 150 illustrations, which was one of the earliest publications of the kind in this country. His more elaborate "Manual for Railroad Engineers and Engineering Students," published in 1873, in two volumes, went through several editions, and made him well known in the railroad world.

The reputation gained by the publication of this work was, in all probability, the cause which led to his appointment, in 1872, as professor of civil engineering in Bowdoin College, at Brunswick, Me. There he remained until 1881, teaching a small but earnest body of students, many of whom have since become prominent in the engineering profession. Among them may be mentioned Charles L. Clark, consulting electrical engineer of New York City; Charles D. Jameson, now consulting engineer for the imperial government in Pekin, China; Capt. Robert E. Peary, civil engineer in the United States Navy, and discoverer of the North Pole; George W. Tillson, chief engineer of the Bureau of Highways, New York; and William H. Chapman, long a partner of the late Col. Geo. E. Waring, of Newport, R. I.

In 1881 the resignation of John B. Henck, as professor of civil engineering at the Massachusetts Institute of Technology in Boston, led to the appointment of Professor Vose as his successor, and he remained in this position until March, 1886, when he resigned. During this period he took a great interest in the affairs of the Boston Society of Civil Engineers, and was its president in the years 1884 to 1887. The later years of his life were spent in retirement at his home in Maine. He was engaged in various pieces of engineering work from time to time, but his health was not good, and he finally passed away peacefully in Brunswick, the scene of his first teaching activity, on the twenty-ninth day of March, 1910.

Professor Vose will probably be best remembered as the author of his railroad manual and as a teacher, and probably most of all as a teacher. He had the power of awakening the enthusiasm of his pupils, and he had so much engineering experience that he was able to illustrate his work in the class room with practical examples, which added much to his efficiency as an instructor. It is probable that the best and happiest period of his work was that between 1872 and 1881, when he occupied the chair at Bowdoin, in a congenial atmosphere, with small classes of men with whom he could come into personal relations. These men learned to know him as his later students at the Institute of

Technology never did, and they always regarded him with affectionate remembrance.

Professor Vose always had a great contempt for shams and pretense, and unhesitatingly attacked any undertaking in which he discerned the slightest dishonesty. He often made enemies by his straightforward utterances, but he was loved and respected by every person with whom he was intimately associated. In his later years, when his failing health prevented him from engaging in active work, he was welcomed as a friend among his old associates of the faculty of Bowdoin College, at Brunswick, Me., where he passed the last years of his life. His later years were much saddened by the loss of four members of his immediate family, his three daughters and his wife. He is survived by one son, Richard Vose, who is now an engineer with the Mexican Central Railroad.

Professor Vose published, in addition to his Handbook and Manual, several other papers, many of them in a popular vein. A list of these is given below:

Handbook of Railroad Construction, 480 pp., 8vo., and 150 illustrations. Published by James Munroe & Co., Boston, 1857.

Paper in *Atlantic Monthly* for November, 1858, on Railroad Engineering in the United States, 15 pp.

Paper on Glacial Theories, in *North American Review* for January, 1863, 44 pp.

Orographic Geology, or the Origin and Structure of Mountains, 135 pp., 8vo. Published by Lee & Shepard, Boston, 1866.

Manual for Railroad Engineers and Engineering Students, 1 vol., 8vo. text, 570 pp.; and 1 vol. with 31 plates. Published by Lee & Shepard, Boston, in 1873, and other editions later.

Paper in *Van Nostrand's Magazine* for July, 1875, on the United States Coast Survey, 12 pp. and 6 illustrations.

Graphic Arithmetic, 1 vol., 16mo., 62 pp. and 28 illustrations, being No. 16 of Van Nostrand's Science Series. Published first in *Van Nostrand's Engineering Magazine.*

Elementary Courses of Geometrical Drawing, 1 vol., large octavo, with 38 plates. Published by Lee & Shepard in 1878.

Bridge Disasters in America, The Cause and the Remedy, 1 vol., 16mo., 89 pp. Published first in the *Railroad Gazette*, and later republished by Lee & Shepard in Boston.

Safety in Railroad Travel, *North American Review*, October, 1882, 12 pp.

Training for Students in Civil Engineering. A paper read before the Boston Society of Civil Engineers, October 18, 1882.

Notes on the History of Early Transportation in Massachusetts.

A paper read before the Boston Society of Civil Engineers, November 19, 1884.

Memoir of Loammi Baldwin, Civil Engineer. A paper read before the Boston Society of Civil Engineers, September 16, 1885. Republished afterwards in pamphlet form.

Memoir of George W. Whistler, Civil Engineer. Read before the Boston Society of Civil Engineers, September 15, 1886. Republished by Lee & Shepard in 1887.

Besides the above, there are numerous papers published in different engineering periodicals from 1860 to 1890, and many articles in newspapers, relating to public works.

ALFRED E. BURTON,
GEO. F. SWAIN,
Committee.

William Jackson.*

MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

WILLIAM JACKSON, for twenty-five years city engineer of Boston, died at his home in Brighton, June 30, 1910.

It is a remarkable tribute to Mr. Jackson himself and to the engineering profession, of which he was a leading and respected member, that from his appointment as city engineer, at the age of thirty-seven, until the day of his death he conducted the affairs of an exacting municipal office, charged with the expenditure of millions of dollars of public funds, so honestly and so efficiently that he stood above politics, surviving all municipal political changes. He was universally regarded as an official whose services were invaluable to the city.

William Jackson was born in Brighton, March 13, 1848, the son of Samuel and Mary Wright (Field) Jackson. He received his early education in the Brighton public schools, and lived there the whole of his lifetime. His training for his life-work as a civil engineer was obtained at the Massachusetts Institute of Technology, where he took the full course with the Class of '68 until May 4, 1868, when he left, without receiving a degree, in order to take a position in the city engineer's office, Boston, on the staff engaged upon the construction of the Chestnut Hill Reservoir of the Boston Water Works. At that time no Technology degrees had been conferred, — their value was not appreciated; and, no doubt, to the youth of twenty an engineering position, with assured remuneration, seemed more attractive than a piece of sheepskin of unproven worth. In after years it was

* This memoir was prepared by Frederic H. Fay for the *Technology Review.*

one of Mr. Jackson's regrets that he had not remained for his degree, and throughout his life his interest in Technology and all that pertained to her welfare was most keen.

From 1870 Mr. Jackson was engineer for the town of Brighton, and in private practice until Brighton was annexed to Boston in 1873, when he again entered the Boston city engineer's office, where for three years he was engaged upon miscellaneous work, including surveys for the introduction of water into Brighton and West Roxbury. From 1876 to 1885 he was assistant engineer on the Boston Main Drainage Works, a notable and difficult engineering undertaking. In April, 1885, upon the sudden death of City Engineer Henry M. Wightman, Mr. Jackson was appointed city engineer, which position he held continuously until his death. In addition to his duties as city engineer, Mr. Jackson, at different times, did other important engineering work. He was chief engineer for the Harvard Bridge Commissioners, 1887–91; chief engineer of Charlestown Bridge, 1896–1900; and chief engineer, Cambridge Bridge Commission, 1898 until his death. In the fall of 1898, in company with Mr. Edmund M. Wheelwright (M. I. T. '75), consulting architect to the Cambridge Bridge Commission, he visited Europe to study notable bridges there preparatory to making designs for a monumental structure for Cambridge Bridge.

He was a member of the Rapid Transit Commission of Boston in 1891–92, and a member of the Boston Statistics Commission from 1898 until he died. From 1902 to 1904 he was a member of the special commission on the abolition of grade crossings in Attleboro, Mass., and at his death had been for three years a member of similar commissions on the abolition of grade crossings in Foxboro, Westwood, Canton, Sharon and Mansfield, Mass. He served as consulting engineer to the Cambridge Water Board upon the construction of the Hobbs Brook Conduit, 1904; consulting engineer to the Shore Road Commission, Brooklyn, N. Y., 1896–97; and consulting engineer to the Massachusetts Harbor and Land Commission on the Commonwealth Dock, South Boston, in 1899. He was also a member of the Approving Board appointed under legislative act in 1907 to pass upon plans for the development and extension of the drainage systems of Boston. On several occasions, when a vacancy occurred at the head of another city department, Mr. Jackson was designated to temporarily fill the position until a permanent head could be selected.

The breadth of Mr. Jackson's interest in general affairs,

as well as in matters pertaining to his profession, is shown by the following list of organizations of which he was a member at the time of his death: Union, Art and Technology clubs of Boston; Boston City Club, Point Shirley Club, Boston Dining Club, Strollers' Club of New York, Allston Golf Club, Commonwealth Riding Club, the Masonic Fraternity, Boston Chamber of Commerce, Technology Alumni Association, Society of Arts, American Association for Advancement of Science, National Geographical Society, Bibliophile Society, National Municipal League, American Civic Alliance, American Civic Association, New England Historical and Genealogical Society, Bostonian Society, Society of Colonial Wars. Of professional societies he had been a member of the Boston Society of Civil Engineers since 1874; a member of the American Society of Civil Engineers since 1884, and a director of that society in 1902–3–4; and a member of the New England Water Works Association since 1890.

Mr. Jackson married, on April 27, 1886, Miss Mary Stuart MacCorry, of Boston. Mrs. Jackson died March 27, 1905. He is survived by a son, William Stuart Jackson.

William Jackson was a man of high ideals and notable ability, modest and unassuming, eminently fair in his dealings with others, and faithful to every trust imposed upon him. Of a retiring disposition, his circle of intimate friends was comparatively small, but to those privileged to come into close association with him he was a true friend and a lovable man. He won the regard and hearty support of his subordinates and inspired the confidence and respect of all who knew him. He was the last man to have willingly permitted words of eulogy to be spoken, and to the many who knew him no eulogy is needed to set forth his life in true perspective. Of the numerous tributes of the press, an editorial in the Boston *Herald* is, perhaps, most representative of the man:

"The record of a life spent in the service of the public is in itself the eulogy of City Engineer William Jackson. From boyhood to death he was a public servant, filling one post of duty after another, meeting every responsibility great or small, preferring public service to the greater emoluments which he might have earned in private enterprise. He was a patriot, even though he shouldered a tripod instead of a musket."

Desmond FitzGerald,
Erasmus D. Leavitt,
Frederic H. Fay,
Committee.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVI. MARCH, 1911. No. 3.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

ANNUAL ADDRESS.

BY FRANK M. SMITH, PRESIDENT OF THE MONTANA SOCIETY OF ENGINEERS.

[Read before the Society at the Annual Meeting, held in Helena, Mont., January 14, 1911.]

Members of the Society and Gentlemen, — In accordance with a provision of our constitution, it becomes my duty to report to you at this, the annual meeting, the condition of the Society and to give an outline of the progress of engineering in the state of Montana during the past year. I am pleased to state that the condition of the Society is most satisfactory. Our Secretary reports the membership as follows:

Active members,	158
Corresponding members,	52
Honorary members,	2
Total,	212

This is an increase of membership of eight during the year. I am also glad to state that the Treasurer's report which has been read to you to-day shows the Society to be in a healthy condition financially.

The regular monthly meetings held in Butte have been fairly well attended, at which matters of general interest to engineers have been discussed informally. During the past year the Society has actively participated in the movement for better roads in the state. This will be mentioned more in detail later in this address.

Engineering progress throughout the state in general has been quite marked, although but few important new works have

been inaugurated. In order to present a comprehensive summary of the various engineering projects on which work has been done in the state during the past year, I will discuss them under the following headings.

1. Work of the United States Reclamation Service.
2. Work of the State Engineer.
3. Construction and Improvements Made by Railroad Companies.
4. Reports of County Surveyors, City Engineers and Municipal Improvements.
5. Work in Charge of the United States Surveyor-General.
6. The Good Roads Movement.
7. Water Power Development.
8. Improvements at Smelters.
9. Mining Operations.

1. United States Reclamation Service.

Mr. H. N. Savage, supervising engineer of the Northern Division, which includes Montana, North Dakota and Wyoming, has kindly furnished the following information, outlining the scope of the United States Reclamation Service and giving an account of the various projects now under construction and in the course of completion in this territory.

The total irrigated area in the United States increased from 3 600 000 acres in 1899 to 11 000 000 acres in 1907.

The projects now being constructed by the Reclamation Service under the Reclamation Act will, when completed, irrigate upwards of three million acres, of which approximately 1 250 000 acres were irrigated during the season of 1910.

The total irrigable area in the United States may be between forty million and fifty million acres, but of course the area feasible of irrigation increases with the demand and value of the land, on which is predicated the maximum cost per acre for the construction of works which the land can safely stand. Projects are now under construction which from a financial standpoint were not feasible ten years ago; and projects which are not now considered feasible because of prohibitive cost will doubtless be put under construction within the next ten years, and prove feasible and profitable.

ORGANIZATION.

The United States Reclamation Service was brought into existence by the Act of Congress approved by President Roosevelt, June 17, 1902. The Act appropriated the receipts from the sale and disposal of public lands in certain states and territories

to the construction of irrigation works for the reclamation of arid lands. The carrying out of the provisions of the Act was delegated to the Secretary of the Interior.

The Act provides for the return to the Reclamation Fund by settlers on the irrigated projects of the total cost of the irrigation works in annual payments not exceeding ten, and without interest. As a result, the cost to the settlers of the irrigation works is approximately two thirds of what the cost would be if the deferred payments were interest bearing. The Act when approved restricted the operations thereunder to the thirteen western states and three territories, which included all the states and territories west of Minnesota, Iowa, Missouri, Arkansas and Louisiana. Texas, although a commonwealth, has subsequently been permitted to avail in part of the benefits of the Act.

The Secretary of the Interior assigned the administration and execution of the work to the director of the United States Geological Survey, Mr. Charles D. Walcott. Mr. Walcott became secretary of the Smithsonian Institution three years ago; and Mr. F. H. Newell, who had previously been chief engineer of the Reclamation Service, was thereupon made director; and Mr. A. P. Davis, who had previously been assistant chief engineer, was advanced to the position of chief engineer.

The field operations, administration and execution of the work of the Service are in the hands of the supervising engineers, who report to the director and are held responsible for the initiation, administration, construction and operation of all the projects and works within their respective territories.

The Reclamation Service investment and cash balance to June 30, 1910, amounted to $60 606 000, and the added receipts to the Reclamation Fund will approximate fifteen million dollars for the years 1910 and 1911. As an additional fund, the last Congress authorized the issue of certificates to the amount of $20 000 000 with which to hasten the completion of projects already begun.

Twenty-six principal projects have been undertaken. Many of these are now practically completed and in operation. Upwards of one million acres were irrigated during the season of 1910. The building cost which must be reimbursed by the settlers varies from $30 to $65 per acre with different projects. The estimated value of the lands due to the construction of the irrigation works and the availability of water for irrigation is, by conservative estimation, $239 500 000, which amount is almost exactly four times the cost of all the works. It may also

be stated that the value of the crops grown in a single season on any completed project will be equal to the total cost of all the works on that project.

Summary of Results, to and including June 30, 1910.

Irrigable Area.	
Area for which water can be supplied:	
Total area, acres	876 684
Actually irrigated:	
Total area, acres	535 335
Canals:	
Class 1, miles	663
Class 2, miles	790
Class 3, miles	3 874
Total miles	5 327
Tunnels:	
Number	68
Total length, feet	96 512
Canal Structures:	
Class 1, number	462
Class 2, number	728
Class 3, number	17 669
Total	18 859
Bridges:	
Number	1 487
Total length, feet	35 561
Roads:	
Miles	460
Telephone Lines:	
Lines miles	1 319
'Phones number	550
Excavation:	
Class 1, cubic yards	57 842 078
Class 2, cubic yards	4 308 489
Class 3, cubic yards	3 971 404
Total	66 121 971
Riprap:	
Cubic yards	286 122
Cement used, barrels	1 133 878
Concrete, cubic yards	961 908

In the Northern Division, which includes Montana, North Dakota and Northern Wyoming, the reclamation works projected will, when completed, bring under irrigation upwards of one million acres. The principal projects are the Sun River, Milk

River, Lower Yellowstone, Huntley, North Dakota Pumping projects and the Shoshone Project in Wyoming, in addition to which investigations have been made of a number of projects, and chief among which are the Helena, Lake Basin and Clark's Fork projects.

SUN RIVER PROJECT.

Average elevation of irrigable area: 3 700 ft. above sea level.

Source of water supply: Sun River.

Area of drainage basin: 1 140 square miles.

Storage reservoirs: Willow Creek, Warm Springs, Pishkun, Muddy and Benton Lake.

Available water supply with storage sufficient for approximately 300 000 acres.

Fort Shaw Unit, 16 377 acres, completed.

The irrigation works consist of 17.3 miles of canals with capacities varying from upward of 300 sec. ft. to 50 sec. ft., and 88 miles of canals with capacity less than 50 sec. ft.

The Fort Shaw Unit is made up of 206 public land farms averaging 80 acres in area, and averaging 61 acres of irrigable land; the farm units varying from 40 to 160 acres in total area. The project was opened to settlement and entry May 7, 1908, and 175 of the farms have already been filed upon. The building charge was announced at $30 per acre. Willow Creek Dam is now under construction by force account to supplement possible deficiencies in the discharge of Sun River in an unusually dry year. The total expenditures for this project to July 1, 1910, amounted to $651 000. The engineers are now considering the construction of the greater Sun River Project, as it is announced that $1 000 000 of the $20 000 000 loan fund will be allotted with which to begin the work.

MILK RIVER PROJECT.

Average elevation of irrigable area: 2 200 ft.

Source of water supply: Milk River supplemented by St. Mary River.

The drainage basin of Milk River includes 4 000 square miles. The irrigable land extends from above Dodson to below Glasgow and includes upwards of 200 000 acres, the entire tract being traversed by the main line of the Great Northern Railway. This was one of the first projects investigated by the Reclamation Service. Construction work has been held up, however, pending the determination of international water rights between Canada

and the United States. A treaty was negotiated and recently proclaimed whereby the rights of the respective governments are defined, and it is expected that a portion of the twenty-million-dollar loan fund will be allotted for the construction of the projected works, chief among which is a diversion canal 26 miles in length to conduct to the Milk River watershed the water to be stored in St. Mary Lake. Of the excavation necessary in the construction of this canal, one tenth of the material has already been moved.

In the Milk River Valley a diverting dam has been constructed at Dodson, having a height of 28 ft. and a length of 380 ft. The first nine miles of main carrying and flood discharge canal has been constructed with a bottom width of 100 ft., and is projected for an ultimate carrying capacity of 1 250 sec. ft. The distributing system to cover the first unit of about 9 000 acres between Dodson and Malta has been completed. Approximately $800 000 has already been expended on this project, including the construction of St. Mary Canal in part and the distributing works for the first unit. Water will be supplied to the lands covered by this unit at the beginning of the irrigation season of 1911.

LOWER YELLOWSTONE PROJECT.

Average elevation of irrigable area: 1 900 ft. above sea level.

Source of water supply: Yellowstone River.

Area of drainage basin: 66 000 square miles.

Average annual run-off of drainage basin, 10 000 000 acre ft.

The irrigable area extends from a point seventeen miles northeast of Glendive along the west side of the Yellowstone River to a point near its mouth opposite Mondak, No. Dak., and involves the irrigation of 63 000 acres of land, 43 000 acres of which are now under completed canals.

The principal features of the system works are the Lower Yellowstone Dam, 12 ft. high and 700 ft. long, designed to pass a flood of 200 000 sec. ft.; a main canal 64 miles long, with a capacity of 850 sec. ft., and 121 miles of lateral canals.

The lands under the project were opened to entry in December, 1908. Water was first delivered in the spring of 1909. About one fourth of the total irrigable area of the first unit has already been put under irrigation, and it is expected that a greatly increased area will be irrigated in the season of 1911. The total cost of the project will be upwards of $3 000 000.

NORTH DAKOTA PUMPING PROJECTS.

On account of the slight fall in the Missouri River it was not practicable to take irrigating water therefrom through gravity canals. The large deposits of lignite coal which were available were utilized for developing power, and water is being pumped from the river for both the Buford-Trenton and Williston projects. The fluctuations of the river, both laterally by reason of its erosion and also of its regimen, made necessary the installation of the initial pumps on floating barges. The barges are put into the stream at the beginning of the irrigation season and connected with the canal system by means of flexible joint pipes, additional sections of which are added or taken away as the changes in the river channel make necessary.

The average elevation of the irrigable area is 1 900 ft. above sea level. The first unit of the Buford-Trenton Project covers 4 060 acres, and the first unit under the Williston Project 8 047 acres. Power for pumping for both projects is developed at a central power station located on the Muddy River three miles inland. Fifteen hundred horse-power is developed and electrically transmitted for the Williston Project pumps and 1 500 for the Buford-Trenton pumping work. The Buford-Trenton power is transmitted 25 miles. The plant has proven successful in operation and the settlers are harvesting bountiful crops and securing ample prices therefor, particularly for garden truck and alfalfa.

HUNTLEY PROJECT.

The Huntley Project, located twelve miles east of Billings, was the first opened to entry by the Reclamation Service in the Northern Division. It is situated along the right side of the Yellowstone River, the average elevation being 3 000 ft. above sea level. The water supply is taken direct from the Yellowstone River by gravity canal. The first unit contains 28 921 acres. Three thousand additional acres will be brought under canals by the extensions now contemplated for construction in the immediate future; 426 of the farm units have already been filed on. The settlers are harvesting bountiful crops, especially of sugar beets, yields of from 15 to 20 tons per acre being secured.

The main canal has a maximum capacity of 450 sec. ft., and within the first unit a length of 23 miles. The laterals aggregate 240 miles and there are 2 654 ft. of tunnel. A portion of the water is pumped to a higher canal, advantage being taken of drop in the principal main canal. The power is developed by

turbine wheels and the water is lifted with a centrifugal pump attached to the turbine shaft.

The expenditures on the project up to June 30, 1910, amount to a little less than a million dollars. The receipts from the payment of the first installment of the building and the operation and maintenance charge amount to upwards of $75 000.

SHOSHONE PROJECT.

The Shoshone Project is located in the northwestern portion of Wyoming just south of Billings, Mont. The irrigable land lies on both sides of the Shoshone River. The project has been designed for the ultimate irrigation of 162 000 acres. The average elevation of the irrigable land is 4 500 ft. above sea level. The farm units contain from 40 to 80 acres of irrigable land and grazing land so far as available to make the total area of the farm units 160 acres. The project is crossed by two lines of the Chicago, Burlington & Quincy Railway. The first two units of the project, aggregating 30 000 acres, have been opened to entry and are about three fourths settled.

The principal features of the constructed works are the Shoshone Dam, Corbett Dam, Corbett Tunnel, Garland Canal and distributing system. Of these, the Shoshone Dam recently completed is the highest structure of the kind in the world. It is of concrete masonry 328.4 ft. high and forms a reservoir with a capacity of 456 000 acre ft. From this reservoir water is discharged into the original channel of the river, down which it flows for 16 miles. It is then diverted by the Corbett Dam, a masonry structure 12 ft. high, with an overflow section of 400 ft. in length extended by an earth section of 400 ft. The water is then taken through the Corbett Tunnel, which is 3.5 miles long, and has a cross section of 100 sq. ft., a capacity of 1 000 sec. ft., and is the supply for the Garland main canal and its distributing system, which, when completed, will cover upwards of 80 000 acres of irrigable land.

The Garland main canal has a capacity of 1 000 sec. ft. This project is one of the larger undertaken by the Reclamation Service and involves many important engineering features. The total expenditures to June 30, 1910, amounted to $3 500 000. It is expected that additions will be made to the distributing works as rapidly as required by the settlement of the project.

The Reclamation Service in this division is also constructing irrigation works in coöperation with the Bureau of Indian

Affairs primarily for the irrigation of lands allotted to the Indians on the Blackfeet, Fort Peck and Flathead Indian reservations. A total of $1 316 000 has been appropriated by Congress and made available, and the major portion of this has been expended. Appropriate arrangements have been made with the Indians on each of these reservations whereby allotments are made to each Indian on the enrollment lists of lands in severalty and the balance of the lands not required for the allotments are appraised and subsequently made available for homestead entry to settlers who make filings and pay in installments the amount of the appraised value of the land. The Reclamation Service engineers employ the Indians with their teams, and as laborers. The irrigation possibilities on these reservations involve large areas. Wherever the canals as constructed command land open to settlement, water for irrigation purposes may be obtained by the settlers upon payment of the pro rata cost of the irrigation works.

The Blackfeet Reservation canals to cover about 10 000 acres of allotted land will be completed by the beginning of the irrigation season of 1911. The total allotment of irrigable land up to the present time aggregates upwards of thirty thousand acres.

Constructed works to cover approximately 10 000 acres of land will be completed on the Fort Peck Project by the beginning of the irrigation season of 1911. There has been allotted to the Indians on this reservation a total of about 90 000 acres of irrigable land. If given an opportunity, the Indians of the Black Feet and Fort Peck reservations will perform the major portion of the work of constructing the canals with which to irrigate their own lands.

The Flathead Reservation works were sufficiently completed to irrigate 12 000 acres during the season of 1910. Additional works will be completed by the beginning of the irrigation season of 1911 to add approximately ten thousand acres more. The Reclamation Service carries on the work by force account and where necessary for economical construction supplies the heavy construction equipment, such as elevating graders, steam shovels, traction engines and sawmills. The total expenditures on the three reservations up to December 31, 1910, amount to approximately $900 000.

The President has recently approved the report of the engineer officers and in connection therewith the allotment of a total of $7 916 000 out of an aggregate of $45 000 000, to the work in Montana. This provides for the completion of the Huntley

and Lower Yellowstone projects in their entirety as originally projected, and the construction of the Sun River and Milk River projects. In addition, sufficient allotments have been made to continue work as rapidly as required by settlement on the North Dakota Pumping Projects and on the great Shoshone Project in Northern Wyoming, which is very tributary to Montana, and when the Chicago, Burlington & Quincy Railway Company's connecting line between Scribner and Fromberg is completed, which will probably be within sixty days, the project will be more tributary than ever, and much nearer by rail to Billings.

2. Work of the State Engineer.

Closely allied to the work of the United States Reclamation Service and the objects to be attained therefrom, is the work of the state engineer of Montana, in carrying out the provisions of Congress under what is known as the Carey Act. State Engineer Mr. John W. Wade has kindly furnished the following information as to the work done under the above Act.

CAREY LANDS.

The state of Montana has made considerable progress toward securing the one million acres of land granted to each of the arid and semi-arid states under the Carey Act.

Segregation under this Act has been asked for as follows:

List Nos. 1 and 7, near Billings,	15 378.11 acres
List Nos. 2, 3, 9 and 11, near Big Timber,	32 647.83 acres
List Nos. 5 and 6, near Augusta,	36 536.42 acres
List Nos. 8, 12 and 14, near Valier,	102 898.27 acres
List No. 10, near Bynum,	134 987.42 acres
List No. 13, near Martinsdale,	20 308.87 acres
List No. 15, near Lavina,	5 142.30 acres
List No. 16, near Sheridan,	22 285.96 acres
List Nos. 17, 19 and 21, near Flatwillow,	84 447.98 acres
List No. 18, near Lima,	7 885.52 acres
List No. 22, near Ericson,	19 644.97 acres
Total acreage,	482 163.65 acres

Of this area a large part is pending before the Department at Washington for approval. Of that part already approved by the Commissioner, a large area has already been fully reclaimed by the state.

The most advanced of these are List Nos. 1 and 7, the

Billings project (under contract with the Billings Land and Irrigation Company); List Nos. 2, 3, 9 and 11, the Big Timber project (under contract with the Glass-Lindsay Land Company), and List Nos. 8, 12 and 14, the Valier project (under contract with the Conrad Land and Water Company).

The Billings Bench, a large tract of fine land under the Billings Land and Irrigation Company's project, is already well provided with water and a highly prosperous and happy farming community occupies it. Where six years ago not a single home existed, now are scores of farms in a high state of cultivation. There are ten schoolhouses for as many school districts in this new settlement, which is being extended wider and longer every month in the year by new settlers under the project. This project will hold more than twice the people now settled upon it with the average farm unit of 70 acres.

This settlement paid in taxes for 1910 over twenty-five thousand dollars.

It is estimated that irrigation enterprises in the neighborhood of Billings have more than doubled the population of that thriving city during the past six years and added to its taxable wealth two and one-half million dollars.

The Big Timber Project comprises very fine lands on both sides of the Yellowstone River near the town of Big Timber, the county seat of Sweet Grass County. The northern tract occupies the sunny slopes just north of the Big Timber Creek. The whole of this tract is now ready for patent and the state has made application for the same.

The entire system of reservoirs and canals is complete, wanting only the small laterals which will be added as the settlement is extended. There has been expended thus far on this north-side system and upon effort to settle same the sum of $350 000 or more. About 2 300 acres are settled and beautiful homes are appearing as if by magic, and cultivation is being rapidly pushed, splendid crops having already repaid effort by industrious settlers.

Work on the south-side tract has also been begun. A small ditch covering a section inaccessible from the main system has been completed.

The two-mile tunnel upon both ends of which work was being pushed had to be abandoned on account of the character of the material encountered. The soft, shaly rock mixed with disintegrating slate and " rotten granite " put the expense of its support at a prohibitive figure, and in consequence the whole

plan of irrigation here must be modified. This will result in the relinquishment of a large part of the original segregation, but what remains still makes a most desirable project which will take the cream of the tract originally applied for. The best lands will be selected out of this large area and irrigated and reclaimed from a lower line of canal. This newly planned system will probably be in operation in the early spring of 1912.

The Valier Project has shown remarkable vigor and brought about results that are marvelous, in spite of the fact that, because of the death of the financier who backed the proposition, active operations have been for some months suspended. The embarrassment is soon to give way through reorganization of the projectors and there seems to be every reason to hope that no serious results will accrue. The project is located in Northern Montana, about the center of Teton County. It is about seventy miles northwest of Great Falls and about one hundred and twenty miles north of Helena. The project is touched by the Great Northern Railway and is traversed from end to end by the Montana Western Railway.

There are several reservoirs covering this project, the largest, Lake Francis, nearly completed. This reservoir will have a capacity of about 170 000 acre ft. About 200 miles of mains and laterals have been built in the canal system and preparations are being made to add many more miles to the same during the coming season. Already two hundred and sixty settlers have purchased homes under the project, and it is confidently predicted that this settlement and adjoining ones of Conrad and Bynum will soon make a community of the proportions of a county — in fact, will become the largest unbroken farming community in the state, covering as it will over a half million acres of land practically in one solid body.

The Teton Project, under contract with Teton Coöperative Reservoir Company, is made practically contiguous to the foregoing through intervening deeded lands to be irrigated by the two systems. This project is to be covered by a system of reservoirs, only one of which may ever be needed. This reservoir will cover eight or nine sections of land in Townships 25 and 26, Ranges 6 and 7 west.

The dam is now far on the way to completion. It is over one-half mile in length and is pronounced by experts to be built of the best material. It is expected that some modification will be called for by the state and the federal government respecting the seepage now observable under this dam, but this can be

accomplished, and when it is done this structure will reflect credit upon the state and the contractors.

Lists Nos. 13 and 15 comprise separate projects on the Musselshell River. The former comprises about 20 000 acres of the most fertile lands of the Musselshell bottom. This project was thoroughly examined as to topography, soil, climate and water resources by Prof. Samuel Fortier, formerly of the Agricultural College at Bozeman (now chief of Bureau of Irrigation Investigation at Washington, D. C.), and pronounced by him to be splendid irrigation proposition. Helena and Missoula parties have this enterprise in hand.

List No. 16 is of lands lying in the Ruby Valley between Sheridan and Dillon. It will be largely a reservoir proposition, but the site is of the very best and the soil good. It seems strange that this late day finds such a tract yet unsettled, for looked at from most any viewpoint, this is a most desirable project.

Lists Nos. 17, 19 and 21 comprise lands near and in part upon the Flatwillow Creek. The first two lists may be abandoned because of the great cost of reclamation revealed by the preliminary surveys. The last named (List No. 21) will probably be pushed to completion. Men of good business standing in Butte and Lewistown have these segregations in hand and promise soon to make definite the matter of contract upon them.

One of the best reservoir sites in Montana is to be utilized to provide water for the lands in List No. 18. The Red Rock Reservoir and Irrigation Company, the promoter and proposing contractor in this proposition, have already put up a very costly dam confining the water of Red Rock River for this system. This dam will be improved and raised much higher and the reservoir will then be capable of delivering water to thousands of acres which without it must lie for decades a useless desert.

List No. 22 has in it about 20 000 acres of fine land which will be reclaimed by waters from the Little Missouri. This is a recent application, and yet one which gives promise of a splendid irrigation proposition which will add much to the taxable property of Custer County.

These Carey projects will be of incalculable value to Montana in the matter of early settlement of our desert lands. The Carey Land Act Board has worked indefatigably to put this form of state reclamation on its feet. It is now an assured success and will always reflect credit upon this board and other state officers who have contributed to this end. The Carey Board will recommend to the incoming legislature that the work of this board

be given to higher state officers, relieving the state examiner altogether, as it is so incompatible with the duties of his office, also eliminating the state engineer from membership on the board except in a clerical capacity, allowing the latter to give most of his time to the field which the increasing number of projects now imperatively demands. Great success is certainly assured to state reclamation under the Carey Act.

3. Construction and Improvements made by Railroad Companies.

Taking up the work of the several great railroads which traverse our state, I beg to submit the following information which has been furnished by the engineers connected with each railroad.

NORTHERN PACIFIC RAILWAY COMPANY.

Mr. W. L. Darling, chief engineer of the Northern Pacific Railway Company, states that grading has been completed for a line running from Glendive northeasterly along the Yellowstone River a distance of 55 miles. This line crosses the Yellowstone River at Glendive, and piers and abutments for the bridge have been completed. It is the intention to complete this work in 1911.

A branch line 23 miles long, running from Mission to Wilsall up the Shields River Valley, has been completed and put into operation.

The main line is being double-tracked between Huntley and Laurel, a distance of 28 miles, and that portion thereof between Lockwood and Laurel, a distance of 22 miles, except for a gauntlet across the Yellowstone River bridge, has been completed.

A second track has also been completed between Missoula and DeSmet, a distance of about 7 miles.

On account of the growing volume of business moving over the main line, automatic electric block signals have been installed between Billings and Livingston, a distance of 115 miles, and are in process of installation between Garrison and Missoula, a distance of 73 miles.

In addition to a number of steel girder bridges, the Northern Pacific have constructed during the year about 2 000 lin. ft. of reinforced concrete trestles, replacing temporary timber and trestle bridges.

GREAT NORTHERN RAILWAY COMPANY.

Mr. P. S. Hervin, resident engineer, reports the following work done on the Butte Division.

Gerber-Armington Change of Line.

This work is now in progress and nearing completion. The work was started during the month of October, 1909, and will be completed the first part of January, 1911. This change of line starts at Gerber and ends at Armington, a distance of 18.766 miles. The old line between these two points is 18.125 miles, the new line being 0.64 miles longer than the old one. The change of line is made for the purpose of reducing grade and curvature.

Maximum grade new line,	0.6 per cent.
Maximum grade old line,	1.5 per cent.
Maximum curvature new line,	3 degrees
Maximum curvature old line,	10 degrees
Total curvature new line,	564 degrees, 17 minutes
Total curvature old line,	1 314 degrees, 57 minutes

This is a considerable reduction both in grade and curvature.

The old line is constructed with 60-lb. rail, while the new line will be laid with 90-lb. rail, fully tie plated and with treated ties.

An experiment is being made on this line with different kinds of tie treatment, there being altogether about twenty different kinds of ties used, both square and triangular; ties of different kinds of wood, — tamarack, pine and fir; different amounts of zinc treatment; different amounts of creosote treatment, and untreated. The classes of ties will be laid in succession and a record will be kept from year to year of the wearing qualities of the different classes of timber and different treatments, which we expect will fully demonstrate what class of timber will give the best result.

The construction of the new line requires about 1 600 000 cu. yd. of material, of which about 40 per cent. is rock, 40 per cent. hard pan and 20 per cent. earth. The rock is mostly of a soft nature and had been handled with steam shovels blasting ahead of the shovel.

For waterways, concrete culverts and cast-iron pipe have been used, requiring 6 000 cu. yd. of concrete. On concrete construction corrugated reinforcing bars have been used and about 420 tons of cast-iron pipe, mostly 36-in. diameter.

There is one tunnel on the line, 1 158 ft. long. This tunnel is through the summit of Belt Hill and constructed mostly through shale and soft rock. Construction was very difficult on account of the large amount of spring water and soft sliding soapstone. The tunnel is of standard size, 22 ft. wide and 16-ft. side posts, with 12-ft. radius arches. The opening is large enough to provide for temporary timber lining and permanent concrete lining 2 ft. thick inside of tunnel, leaving finished tunnel 16 ft. wide and 22 ft. clearance above top of rail. Concrete lining has been postponed until spring.

Track laying will be started as soon as weather will permit in the spring, and track will be given a full raise of ballast, 10 in., underneath the ties.

The cost of the work will be approximately $1 300 000. The grading work is done by Contractor A. B. Cook & Co., Helena, Mont. Track work and ballasting will be done by the railway company.

SUN RIVER LINE.

This branch line is from Vaughn to Augusta, 40 miles long, and follows the Sun River the entire distance. Only a small amount of grading was done this season, amounting to about five miles, and work has been postponed until next season.

The road runs on the north side of the Sun River from Vaughn to Sun River Post Office, where it crosses and follows the south side of the river to Fort Shaw and Simms, and crosses the south fork near Augusta.

GREAT NORTHERN MAIN LINE.

Mr. J. H. Ellison, of Winston Bros., contractors, reports the completion of the construction of the second track for the Great Northern Railway Company between Summit and Java, a distance of about 14.4 miles. This construction included a considerable amount of line revision, which consisted principally of reduction of curvature, some curves being thrown out entirely. The maximum curvature on the main line is 8 degrees, whereas the former maximum was 10 degrees. No change was made in the grade, which still remains 1.8 per cent. This construction would be characterized as heavy work, running nearly 100 000 yd. per mile, of which a large percentage was rock.

CHICAGO, MILWAUKEE & PUGET SOUND RAILWAY COMPANY.

Mr. W. H. Penfield, engineer of construction, reports as follows:

Surveys were made for a line from Melstone, a point on the main line in Fergus County, down the Musselshell River to Weede, and from that point west to Great Falls, via Lewistown.

A section of this line, 24 miles long, extending from Lewistown easterly toward Grass Range, was graded this season, and also 12 miles of a line from Lewistown to Kendall, in the country lying between the North Moccasin and Judith Mountains. Track will be laid on these two lines during the coming season.

The White Sulphur Springs & Yellowstone Park Railway Company has been completed, and is now being operated between Ringling, a point on the main line of the Chicago, Milwaukee & Puget Sound Railway, in Meagher County, north to White Sulphur Springs. This line has been built and is owned by John Ringling, of Baraboo, Wis. It is 22.85 miles long, and was built to give access by railroad to the springs at White Sulphur.

The Gallatin Valley Railway Company have completed, this season, and are now operating their Three Forks extension, which was built from Bozeman Hot Springs to a connection with the Chicago, Milwaukee & Puget Sound Railway at Three Forks, a distance of 27.2 miles. They have also completed and are now operating a branch from Camp Creek Station on their main line, to Belgrade, a distance of 5 miles.

BIG BLACKFOOT RAILWAY COMPANY.

(Information furnished by Mr. F. W. C. Whyte.)

This is a subsidiary company of the Big Blackfoot Milling Company, incorporated for the purpose of building a connection from the saw mills at Bonner (near Missoula) to the logging tracks in the timber. Some years ago this company built a series of tracks from the timber, which delivered the logs into the river at the mouth of Camas Creek, some 11 miles from Bonner, the logs being driven the intervening distance each spring. In order to enable the mills, if required, to run all the year round, and to avoid the river driving expense, it was decided to connect the logging tracks with the mills. During the year 11 miles were graded complete, including some very heavy rock and two crossings of the Big Blackfoot River. The first of these at Bonner is composed of three 80-ft. deck girder spans and one 50-ft. girder span of heavy concrete piers, with about 112 ft. of trestle

approach at one end. The other at the mouth of Camas Creek is composed of two 100-ft. deck Howe truss spans with pile approach on either end.

Reports have also been received from the engineers connected with the Oregon Short Line, Butte, Anaconda & Pacific Railway Company, and the Chicago, Burlington & Quincy Railroad Company, on none of which roads, however, has any new construction work been undertaken, with the exception of the grading for the new line between Scribner and Fromberg by the Chicago, Burlington & Quincy Road.

4. Reports of County Surveyors, City Engineers and Municipal Improvements.

Inquiries were addressed to the county surveyors of each county and likewise to the city engineers of the principal cities and towns. To all those who so promptly and courteously sent replies, I wish to express my thanks. My only regret is that lack of space precludes the possibility of recounting in detail the interesting work being carried out by the county surveyors and city engineers of the state. The county surveyors are all in thorough sympathy with the movement for good roads, but they are considerably handicapped in the accomplishment of permanent results by the inadequate system which prevails in this state of having all work done by road supervisors appointed by the various boards of county commissioners. It is to be hoped that this system will soon be changed so that the main highways of the state will be under direct supervision of the various county surveyors acting under the direction of a State Highway Commission, or a State Road Commissioner. I should like to have space to speak of the municipal improvements under way in a number of the larger cities of our state, and particularly of the work of the Park Commission in Great Falls, Missoula and other cities. The improvements made in the water supply system of Butte are worthy of mention.

BUTTE WATER COMPANY.

The city of Butte receives its water supply from the Big Hole River, being pumped clear over the Continental Divide, overcoming an elevation of 840 ft. A large electric pump has been installed during the past year at the Big Hole Station, having a capacity of 4 000 000 gal. of water per twenty-four hours.

Mr. Eugene Carroll, manager of the Butte Water Company, gives the following information as to the improvements installed during 1910.

The original station was built as a steam plant, having two horizontal triple expansion, three crank, direct connected Nordberg pumps, operated by a battery of Sterling boilers. During the past year No. 2 pump has been changed to an electrically driven pump in such a way that it can be run either by steam or electricity. To do this that part of the pump station was enlarged and a rope-driven shaft and motor placed at the south end of the pump, joined by connecting rods to the tail pieces of the water ends. By this arrangement the steam end is disconnected when the electrical end is working, and in case of accident to the motor it can be quickly disconnected and reconnected to the steam end. An 800 h.p. motor has been installed to operate this pump, driving two 24-ft. rope wheels with twelve $1\frac{3}{4}$-in. ropes on each sheave. The motor is interesting from the fact that it is connected to run in synchronism with the water wheels at the Big Hole Station of the Great Falls Water Power and Townsite Company. By this means the speed of the pump can be varied at will or it can be connected into the general circuit of the power company, extending from Great Falls. This pump has a working pressure of 369 lb. on its water end, and in order to start it three 4-in. by-passes are used. In starting, all by-passes are left wide open, and after the pump attains speed are gradually closed, so that we are enabled to have the pump in full operation within a few minutes after starting.

The results so far in the operation of this station by electricity have been very satisfactory and the saving in operating expenses is considerable. The boiler plant and No. 1 pump are kept in working order so that at any time, should it become necessary, the steam plant can be started. While it is not claimed that this is the biggest pump in the world, I believe it has the distinction of being the longest pump in existence, the distance from the tip of the fly wheel of the steam end to the back of the sheaves on the motor being 131 ft. 6 in.

The West Side Station of the Butte Water Company was electrified in the year 1909 by the erection of a variable capacity Nordberg rope-driven pump. This pump is made variable capacity by a contrivance which lengthens or shortens the stroke at will, and was made necessary from the conditions at that station, where the rate of consumption varies during the twenty-four hours. A contract has been let and the machinery

is now being erected at this station for an additional rope-driven electrical pump having a capacity of two million gallons in twenty-four hours. This has been placed so as to have duplicate machinery in that station driven by electricity.

In addition to this work at the Pump Stations, the Water Company has made large extensions of water mains in the southwestern part of the city, made necessary from the fact that a large territory has recently been annexed and taken within the city limits. After the erection of the new pump at the West Side Station the plant will be in complete duplicate, in addition to the further possibility of supplying the entire system from the large storage reservoir built in 1908. The company now has five distinct sources of supply, with three independent supply lines, and is so arranged that any one of the supplies can be utilized in any part of the system.

5. United States Surveyor-General's Office.

Mr. J. F. Cone, United States Surveyor-General for Montana, reports the following work accomplished under his supervision during the past year.

Ninety townships representing about 5 200 lin. miles, or approximately 1 700 000 acres, have been surveyed, involving an expenditure of about $60 000.

Congress appropriated for the year for the survey of public lands a total of $120 000, of which $80 000 was to be used in surveying lands in the four eastern counties with the idea of giving preference to lands either settled upon or which are most in demand for settlement; the remainder of $40 000 to be used for the survey of lands in other portions of the state where the same conditions prevail. It is estimated that if the same amount is appropriated for surveys in this state each year, the survey of the entire state will practically be completed in about five or six years.

It might be interesting to the members of the Society to learn that a radical change in the method of surveying the public lands of the United States has taken place during the past year.

On June 26, 1910, Congress passed an Act abolishing the old contract system and substituting instead the salary system. Under this new system the public surveys are made by the United States surveyors, who are paid regular salaries and who operate under the direct supervision of field supervisors. It is believed that in this manner much better results will be obtained

as there is no incentive to slight the work such as obtained under the old system, and indeed this statement has already been verified by the results accomplished during the three months of field work done under the new system.

In addition to the subdivisional surveys above mentioned, 260 mining claims have been surveyed and approved during the past year. This is much below the average for the past decade, but is accounted for by the lack of mining activity which prevails in this as well as other western states.

Of the mining claims surveyed, each mining district in the state contributed; the Corbin-Wickes district, however, contributed more than any other.

There are fifty-eight commissioned United States mineral surveyors in this district.

6. Good Roads Movement.

If I am not mistaken, this Society was the first organized body that took official action toward the inauguration of the movement for good roads. At the last annual meeting of the Society, held in Butte in January, 1910, a resolution was passed directing your President to appoint a committee to investigate the subject of good roads, gather information as to what has been done in other states, and report their recommendations to the Society at a later meeting. At about the same time, the governor of the state, the Hon. Edwin L. Norris, became actively interested in the Good Roads Movement, and shortly afterwards issued a call for a Good Roads Convention, to be held in the city of Billings, in June, 1910. Among the delegates appointed were five from the Montana Society of Engineers, including our Good Roads Committee, who attended the convention, and contributed not a little to the good work that was accomplished at that convention. This convention proved of great educational value, and stimulated a strong sentiment in favor of good roads. Mr. Clinton H. Moore, the Secretary of our Society, was one of a committee of five appointed by the governor to draft a "good roads" law for presentation to the present legislature.

With a view to testing the efficiency of convict labor on roads, the state prison board last fall undertook the construction of a piece of state road between Deer Lodge and Garrison, and also a portion between Deer Lodge and Helena, entirely by use of convict labor. The old county road between Deer Lodge and Garrison was followed, no changes being made in alignment.

Where grades were followed they were adjusted chiefly with a view to securing good drainage and to avoid deep cuts and high fills. In the road grading there was no wasting of excavation, material from cuts being placed in fills. The finished roadbed is 24 ft. wide at the crown, excepting for about 600 ft. where it was reduced to 18 ft. on account of the narrowing of the right of way. The work was done largely with one breaking plow, a grading machine, five $1\frac{1}{2}$-yd. dump wagons, and three or four slips. No roller was available for the work. Special attention was given to drainage. Ditches were placed on both sides of the road, and where necessary to carry off the water, culverts were put in. The ditches were usually 36 in. wide, and at least one foot below the old roadbed. Three reinforced concrete bridges were erected, one being of 11-ft. span and one a 12-ft. span, both being of slab floor construction. The third bridge was a 14-ft. arch span. In addition, fourteen arched concrete culverts from 1 ft. to 3 ft. span were built on this line. All wooden bridges and culverts were removed and replaced by concrete structures. An average of 40 prisoners, including cook and camp hands, performed all the work, only three guards being in charge of the gang.

During the summer of 1910, the same force of prisoners that worked on the Garrison road improved three miles of county road between Deer Lodge and Helena. No attempt at any time was made by any of the prisoners to escape, the reason for this being doubtless that the state prison board allows a reduction of one day in the sentence of each prisoner engaged in the work for every three days' work on the road.

7. Water Power Development and Transmission Lines.

Among the important water-power developments and electrical construction on which work has been done during the past year are the following.

The Hauserlake and Wolf Creek dams on the Missouri River, belonging to the United Missouri River Power Company.

The Rainbow Falls dam of the Great Falls Water Power and Townsite Company and steel pole line to Butte.

The Missoula Light and Water Company.

The Clark-Missoula Power Company.

HAUSERLAKE DAM.

The Stone & Webster Engineering Corporation has the contract for building a concrete gravity section dam at Hauser-

lake, 18 miles northeast of Helena, to replace the steel dam which washed out in April, 1908. This is a most interesting and difficult piece of construction. The following information concerning the work has been furnished by Mr. George O. Muhlfeld, construction manager for the Stone & Webster Engineering Corporation.

The bed rock is some 65 ft. to 70 ft. below the normal level of the river, and the problem of unwatering the site has been a most difficult one. From the latter part of last year and until the first of May of this year, the entire Missouri River was carried across the site of the dam by means of a flume some 50 ft. wide and 15 ft. high. By the use of this flume and continuous pumping, a large part of the concrete was put in on solid bed rock up to a few feet above the normal river level before the flow of the river exceeded the capacity of the flume in the latter part of April. The greater part of the dam below normal river level was constructed before this flood, and a subcontract was then given to The Foundation Company of New York by the Stone & Webster Engineering Corporation, to complete the remaining portion of the dam unfinished below the river level by means of the pneumatic caisson method.

The Foundation Company has built a line of cofferdams, both on the upstream and downstream side of the dam, connecting to solid rock on the west side and to the completed portion of the dam on the east side. These cofferdams have been built by sinking seven pneumatic caissons and it is expected that they will unwater the area between the upstream and downstream line of caissons early in January. As soon as the site is excavated and the concrete brought to the river level, the work will then be completed by the Stone & Webster Engineering Corporation's own forces.

While The Foundation Company has been engaged in sinking its caissons, the Stone & Webster Engineering Corporation's own forces have entirely completed about 75 per cent. of the dam, including the flashboard structure.

WOLF CREEK DAM.

The United Missouri River Power Company has also started construction of another dam on the Missouri River at a point called Holter, near Wolf Creek on the Great Northern road.

MISSOULA LIGHT AND WATER COMPANY.

(Reported by Sydney R. Inch, Manager.)

It has constructed a 50-mile, 45 000-volt, 3-phase transmission line throughout the Bitter Root Valley from Missoula to Hamilton, serving all towns en route. This construction followed the securing of a light and power franchise at Stevensville, Mont., and the purchase of the light and water plants at Hamilton, Mont. The line is designed for the delivery of 3 000 kw. at the receiving end at Hamilton, and the initial installation in transformer capacity for the entire line is 1 000 kw.

During the year an entire reconstruction of our district heating system at Missoula has been carried out and a concrete tunnel, 6 ft. by 4 ft. inside dimensions, has been constructed throughout the principal business district of the town, through which our steam and hot water mains are conducted. It is expected that this tunnel will also serve a useful purpose in connection with the underground distribution of electrical power when conditions make it necessary for us to abandon any portions of the present overhead distributing system.

CLARK-MISSOULA POWER COMPANY.

During the year it has installed an additional 1 000 h.p. capacity at our Bonner plant; this, however, has called only for the installation of additional power-house equipment, since the hydraulic equipment was completed when the plant was first constructed.

RAINBOW FALLS.

In July, 1910, the Great Falls Water Power and Townsite Company completed its Rainbow Falls dam and power plant, with a total capacity of 33 000 h.p. The plant and transmission line to Butte represents an expenditure of $4 000 000, the time of construction occupying twenty-two months and fifteen days. The Rainbow development is one of the most up-to-date in the country. The dam consists of a rock-filled timber crib dam situated immediately above the crest of Rainbow Falls. It is 26 ft. high, 1 146 ft. in the spillway, 67 ft. wide on the base, with an apron 49 ft. wide on the downstream side to direct the flow of water and to protect the natural river bed below the dam. At the south, or left-hand, end of the dam are located five waste gates, each 8 ft. wide by 10 ft. high, set in heavy concrete

masonry. These gates are provided with heavy hand-operated mechanism and are capable of discharging under a 26-ft. head about 9 000 cu. ft. of water per second. From the gate abutments the spillway and apron section of the dam are continuous for the entire length of the spillway, an angle being introduced, close to the center, deflecting the north or right-hand end downstream about 24 degrees. At this end of the spillway a heavy abutment wall extending 12 ft. above the crest of the spillway is provided which is made a part of the head gate and cut off wall masonry. The head gates are set parallel to the north bank of the river and are therefore parallel to the flow of the stream. The head works consist of eight 8-ft.-diam. steel tubes set at right angles to the flow of the stream in heavy concrete masonry. These tubes take water directly from the pond above the dam through heavy, iron bar screens, and discharge it into a small basin. From the basin the water is conducted by two steel penstock tubes, each 15 ft. 6 in. in diameter, 2 400 ft. downstream to a large regulating reservoir, which is situated on the north bank of the river, above the power house. This reservoir is inclosed on three sides by massive concrete walls enclosing a basin about one acre in its extent. On the front or stream side are located 12 gates and penstock tubes for controlling the water as it enters the turbine units. On the downstream end there is an ample spillway for the care of surges and high water, with a channel to conduct such overflow back to the river below the power station.

The power house is a brick and steel structure, 326 ft. long by 80 ft. wide. The installation consists of six 57-in. S. Morgan Smith & Co.'s special turbine water wheels, operating under 108 ft. head, directly connected to six General Electric Company's generators, 3 500 kw. capacity at 6 600 volts, 60 cycles, 3 phase. The current generated is transformed to 102 000 volts for transmission to Butte and Anaconda. The transmission line to these cities is a double one and is the longest of such substantial construction in the world. In place of poles, steel towers 45 ft. high are used for carrying the copper transmission wires. This pole line extends in nearly a direct line from Rainbow Falls (about four miles below the city of Great Falls), 126 miles to Butte, and 27 miles further to Anaconda. The power transmitted to Butte is used for operating the Anaconda Copper Mining Company's mines, and that delivered at Anaconda for operating the Washoe smelter, belonging to the same company.

8. Improvements at Smelters.

The great smelting plants of our state have been actively operated during the past year although no very marked improvements or new construction have been carried out with the exception of a certain amount at the East Helena Plant of the American Smelting and Refining Company.

BUTTE.

The only smeltery now being operated in Butte is the Pittsmont plant which was built by the Pittsburg and Montana Copper Company, but has recently been purchased and is now operated by the East Butte Copper Mining Company. No improvements have been reported as being made at this smeltery.

The past year has witnessed the closing down of the old Butte Reduction Works, which for many years was operated by Senator W. A. Clark for the reduction of the ores produced from his own mines in Butte. The Anaconda Copper Mining Company has recently acquired from Senator Clark all of the copper mines which he owned in the Butte camp, and likewise the smelting plant above referred to, which was immediately closed down and the ores formerly treated at that plant are now being sent to the Washoe Plant at Ancaonda.

WASHOE SMELTERY, ANACONDA.

This plant has been operated throughout the entire year, although at a somewhat reduced capacity during the past few months. This was a result of general curtailment in copper output agreed upon last summer between the principal copper producing companies in the world. Mr. Wm. Wraith, superintendent, reports that practically the only improvement installed has been in the roasting plant and in connection with some tests they are making with their reverberatory furnaces. Experiments have been made which demonstrate that they can burn Belt coal quite satisfactorily in their reverberatories and smelt from 260 to 300 tons of cupreous material per twenty-four hours. This is accomplished by making a gas producer out of a fire box, that is, burning the coal at a low rate per square foot of grate area (about 20 lb.) and carrying a bed of coal from 5 to 7 ft. in depth, according to whether natural draft or forced draft is used. By doing this, heavy clinkering of the coal is avoided, which, in conjunction with a shaking grate keeps the fire active

and produces a gas that can be burnt in the furnaces very readily, giving splendid combustion and a good heat.

Certain experiments are being conducted in the converter department in connection with the use of basic line converters, but as yet the results of these experiments are not available for publication.

B. & M. SMELTERY, GREAT FALLS.

The well-known plant of the Boston and Montana Company at Great Falls is now known as the B. & M. Reduction Department of the Anaconda Copper Mining Company. Mr. A. E. Wheeler, superintendent, reports that there has been very little construction on this plant during the past year, most of the work being on repairs and on the maintenance of the plant. A substation has, however, been installed for the receipt and distribution around the plant of the new electric power which they are now receiving from the Rainbow Falls development. Mr. Peter Thill, the master mechanic, has furnished the following description of this substation.

Upon the determination of the Great Falls Water Power and Townsite Company to develop power at Rainbow Falls of the Missouri River, the Boston and Montana Consolidated Copper and Silver Mining Company contracted with them for power. This necessitated the construction, at the smelter plant, of a substation for the receipt and distribution of this power. This substation, as constructed, is part of the main power house of the smelter, which is located on the north bank of the Missouri River at Black Eagle Falls.

The station consists of two stories: the lower 14 ft. high, the upper 18 ft. in the clear, with a dormer 6 ft. above the powerhouse roof, for light and ventilation. Each of the rooms is 90 ft. long by 36 ft. wide. Three sides are of solid brick wall, the east side being open to the power house.

The second floor is equipped with a 10-ton overhead hand crane, for handling machinery on any part of the floor.

The lower floor is of concrete on bedrock. Here are located six 200-kw., single-phase, 60-cycle transformers, to reduce the voltage from 6 600 to 2 200, and three 150 kw., single-phase, 60-cycle transformers, to reduce the voltage from 6 600 to 440, all of which are water cooled. Above the transformers there are located disconnecting switches of 15 000-volt capacity.

The upper floor, which is constructed of steel and concrete, supported by cast-iron columns, furnishes floor space for the

switchboard and motor generator sets. There are three motor generator sets, each being of the three-bearing type and having a cast bed plate, resting on the concrete floor. The motors of each set are 450 h.p., 60 cyles, 6 600 volt, and of the induction type, direct connected to a 300-kw., 500-volt, D. C. commutator pole generator by flange couplings. These generators are run at 720 revolutions per minute, and are compound wound, having a high efficiency at from three quarters to full load, also having a capacity of 100 per cent. overload momentarily.

The switchboard consists of 43 panels, of natural black slate, and is 70 ft. 4 in. in length, and 90 in. high. Each panel is divided into three sections, of 30, 28 and 32 in. in height, and from 16 to 32 in. in width, according to the capacity of its circuits. These panels are mounted on pipe framework, 12 ft. from the rear wall, allowing ample room for inspection.

All alternating current circuits are controlled by remote automatic oil switches, located 6 ft. back of the switchboard, in concrete cells. These cells are provided with slate doors; each circuit on the face of the board has an inverse time limit relay and automatic alarm. By the use of this switchboard there are controlled two incoming 6 600-volt lines of 5 000 kw. capacity, connected with the Rainbow Power Station, and these are distributed into forty-one feeder circuits, three motor circuits and three 550 D. C. generator circuits. These are subdivided as follows: Six 6 600-volt, 3-phase; ten 2 200-volt, three-phase; eight 440-volt, three-phase; eight 2 200-volt, single-phase; six 550-volt, D. C. metallic; and six 550-volt, D. C. single polarity.

The incoming lines consist of twelve No. 0 bare wires and are well protected by lightning arresters outside of the station.

All 6 600-volt oil switches are provided with a single-pole disconnecting switch on each side, and all the above switches are rated for 15 000 volts. The twelve 550-volt D. C. circuits are each connected with a magnetic blowout circuit breaker on switchboard to protect the 550-volt D. C. generators.

The A. C. station, or load panel, is provided with three curve drawing instruments, the first of which records the volts, the second the power factor, and the third the kilowatts. There is a recording watt meter which records the kilowatts of the incoming lines minus the transformer losses, also three watt meters recording the total power respectively of the 2 200-volt three-phase, 440-volt three-phase, and the 2 200-volt single-phase.

Each feeder circuit has an indicating instrument, also a recording watt meter, which gives an accurate account of all power used by the different departments throughout the entire works.

All wires and cables leading from the switchboard are laid in wood-fiber conduits and imbedded in concrete for the entire distance to the different departments of the works which supply current for motors ranging from 5 to 600 h.p.

EAST HELENA PLANT OF THE AMERICAN SMELTING AND REFINING COMPANY.

This is essentially a lead smelting plant and the only one in Montana. At this plant is treated considerably more than one half of the entire output of lead ores and concentrates from the Cœur d'Alene district in Idaho. The plant consists of four 48-in. by 136-in. blast furnaces having a combined capacity of about 800 tons of charge per day. The roasting department consists of a complete Huntington-Heberlein plant, including four Godfrey mechanical roasters and twelve converter pot stands. The greater proportion of the ores treated in this Huntington-Heberlein plant are converted direct in the pots without preroasting, which can be done successfully where the original sulphur contents of the charge do not exceed 10 per cent. Matte and ores running high in sulphur are preroasted in the Godfrey furnaces before being converted in the pots.

The marked success which attended the experiments made with the small 30-in. by 150-in. Dwight & Lloyd sintering machine in the summer of 1909 prompted the company to install two more machines of similar type, but of twice the capacity of the smaller machine. This new installation has been under construction during the whole of the past year and is now in successful operation. The plant consists of two 42-in. by 264-in. Dwight & Lloyd sintering machines, having an effective hearth area and a theoretical capacity of 2.4 times that of the small machine, which was fully described in a paper read by the writer at the last annual meeting of the Society held in Butte last January, and published in the July number of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The new sintering plant is equipped with devices for mechanical handling of the ores throughout. Except in freezing weather the ores are trammed from the mixture beds and dumped in a hopper which discharges over a feed belt on to a 12-in. conveying belt which conducts the ore to a set of corrugated

rolls. These rolls discharge into a screw-conveyor pug-mill-mixer, where a proper amount of moisture is incorporated with the charge. From the pug-mill-mixer the ore is then carried by a bucket elevator to the top of the building and discharged on to a belt conveyor from which it is distributed by means of a Robins automatic tripper in uniform layers in the storage hoppers of both machines. From the storage hoppers the ore automatically drops into the feed hoppers of the machine. Back of the feed hoppers is located the lime rock hopper from which a very thin layer of crushed lime rock is fed on to the grates in advance of the ore feed and to prevent fine ore sifting through the grates. The ignition of the charge is accomplished by means of a gasoline jet, similar to that of the smaller machine.

During the winter months a serious problem at this plant is the matter of handling the frozen lead slimes and concentrates from the Cœur d'Alenes. It being impossible to treat frozen lumps of ore successfully in the Dwight machine, provision has to be made for crushing and thawing this frozen material. It was therefore decided to attempt to utilize the heat of the waste gases from the sintering machine for thawing the frozen ore. The hot gases from the sintering charge are sucked down through the grates by means of two 100-in. Sirocco fans made by the American Blower Company. These fans are operated by direct connected motors and are set on top of a brick flue, into which the gases are discharged by the fan. For a distance of about 80 ft. this flue has been covered with a sheet iron top over which has been installed a scraper conveyor. After the frozen lumps have been crushed by means of a set of toothed rolls, the crushed material is fed on top of one end of this flue and is slowly carried along over the hot sheet iron flue by the scraper conveyor, discharging at the other end on to the same belt conveyor leading to the pug-mill-mixer. This feature of the installation is not entirely completed, but the experiments so far made seem to indicate that it will be a success.

These two sintering machines will have a combined capacity of over 200 tons per day, and will entirely replace the sixteen reverberatory roasting furnaces which had a total capacity of only 170 tons per day.

The advantages to be derived from these sintering machines are, —

(1) Very greatly reduced operating costs as compared with reverberatories.

(2) The product is a hard sinter, containing 3 per cent. to

4 per cent. sulphur, as compared with the fine calcines produced by reverberatories, the former being a much more desirable product for the blast furnaces.

(3) Flue dust to the extent of 15 per cent. to 20 per cent. of the mixture can be sintered successfully, thus avoiding the expensive and unsatisfactory briquetting of flue dust.

(4) Matte to the extent of 50 per cent. of the charge, if necessary, can be sintered.

(5) Very fine concentrates and slimes can be sintered, making a much better product for smelting than when roasted in reverberatories or by the Huntington-Heberlein process.

Other improvements at the East Helena Plant during the year were, —

(1) The building of a new inclined skip hoist for handling crushed Huntington-Heberlein product to storage bins for the blast furnaces.

(2) The building of a new machine shop, fully equipped with power machines for handling practically all of the repair work of the plant.

9. Mining Operations.

The past year has witnessed the absorption by the Anaconda Copper Mining Company of all of the Butte mines, formerly controlled by the Amalgamated Copper Company, which was purely a holding company, together with the Stewart, Original and other copper mines, formerly owned by Senator W. A. Clark. As before stated, the operation of the Butte mines has been curtailed somewhat during the past year so that the total production of copper for the year 1910 will not reach that for the year 1909, although exceeding the production for the year 1908. The total production of all the copper mines in the Butte camp for the year 1910, expressed in pounds of copper, is as follows:

January	19 224 250
February	13 755 620
March	24 757 700
April	25 087 200
May	28 363 760
June	26 356 200
July	24 303 500
August	24 762 800
September	22 990 050
October	22 913 781
November	23 636 550
December	22 500 000
Total	278 651 411

The above total compares with 306 147 610 lb. in 1909, and 268 272 420 lb. in 1908.

METAL PRODUCTION FOR 1910.

The director of the Mint estimates the production of gold and silver in Montana during 1910 as follows:

	Ounces.	Value.
Gold	167 651.91	$3 465 364
Silver	11 519 059.00	6 105 101
Total		$9 570 465

The United States Geological Survey estimates the total copper production of Montana as about 285 000 000 lb. for 1910, as compared with 314 858 291 lb. for 1909; and the toal lead production in Montana for 1910 as approximately 3 600 000 lb., as compared with 3 083 430 lb. for 1909.

USE OF COMPRESSED AIR FOR HOISTING IN THE BUTTE DISTRICT.

Mr. C. W. Goodale, of Butte, has furnished the following information regarding the experiments being made by the Anaconda Copper Mining Company in the use of compressed air for hoisting.

The most important construction work in the Butte Mining District during the past year has been the installation of machinery for furnishing compressed air to the hoisting engines of the Mountain View, High Ore and Diamond mines.

In this plant are three Nordberg compressors, each having a capacity of 7 500 cu. ft. of free air per minute. They are driven by Westinghouse synchronous motors, which receive their current from the Rainbow Falls of the Missouri River, 132 miles distant, and have a capacity of 1 200 h.p. each. The compressors are of the cross compound type, the air being compressed to 26 lb. in one cylinder, from which it passes through an intercooler, thence into the second cylinder, where it is brought up to 90 lb., and discharged into 24 receivers, 10 ft. in diameter and 30 ft. high. Thence an 18-in. pipe line will carry the air to 10 hydrostatic pressure receivers, 10 ft. in diameter and 56 ft. 8 in. long, which will be operated in connection with a steel water tank 100 ft. in diameter and 10 ft. deep, located with them by a 42-in. pipe line.

As the tank will contain 500 000 gallons, it will act as a governor in maintaining a pressure of about 90 lb. in the receivers, and will displace 66 840 cu. ft. of air, if the compressors should stop at any time. In other words, the hoisting engines may run for several minutes on this storage of air, with the compressors shut down.

From the hydrostatic receivers pipe lines will convey the air to the several mines, where additional air storage will be provided, and also boilers and heaters which will reheat the air to a temperature of 350 degrees fahr. before it is used in the cylinders of the hoisting engines.

The present steam cylinders on these engines will be replaced by larger ones, as the air pressure, 90 lb., will be much less than the pressure now carried in steam.

The new machinery will be in use very soon, and if calculations regarding its efficiency are confirmed by results, the equipment will be more than doubled in capacity, and the system will be applied at all the properties of the Anaconda Copper Mining Company.

ZINC ORES.

The past few years have demonstrated that there are enormous deposits of zinc ores in the Butte camp, and these deposits have been extensively exploited during the year 1910. The principal zinc properties in Butte are those owned by the Butte and Superior Copper Company and those of the Elm Orlu Mining Company, the latter being owned by Senator Clark. The Butte and Superior Company, I understand, is treating in the neighborhood of 400 tons per day of zinc ore at the Basin concentrator. A zinc concentrate is produced carrying between 40 per cent. and 50 per cent. zinc, which is shipped to eastern zinc smelters for refining. In turning over the Butte Reduction Works to the Anaconda Copper Mining Company, Senator Clark reserved the concentrator of this plant for the treatment of the zinc ores produced by the Elm Orlu Mining Company. In the neighborhood of 400 tons per day of zinc ore are being treated at the Butte Reduction Works, the resulting concentrate averaging about 50 per cent. zinc and 20 oz. of silver. The crude ore going into the concentrator contains about 20 per cent. zinc. The old concentrator at the Butte Reduction Works was designed for the treatment of copper ores, and according to Mr. A. H. Wethey, general manager for Senator Clark's properties, many changes had to be made in this copper con-

centrating plant to get good results on the zinc ore. There have recently been added to this plant six Callow screens and six Wilfley tables. In the operation of the Basin concentrator and likewise that of the Butte Reduction Works, it is aimed to produce a zinc concentrate as free as possible from iron and lead, and in consequence a leady-iron concentrate is produced, as a by-product, and sold to lead smelters.

Mining in Montana outside of Butte has not been very active during the past year. Most of the old mining camps which were active years ago are now, due largely to the low price of silver, either closed down or operated in a small way by leasers. A notable exception to this rule is the camp at Elkhorn where the Elkhorn Silver Mining Company has produced an average of 2 000 tons of silver ore and concentrates per month during the past year. A marked revival of the old camp of Radersburg, in Broadwater County, has occurred during the past year, and this camp has now several producing mines of great promise.

In this address I have departed somewhat from the custom of former presidents, and at the risk of wearying you with a mass of detail, I have attempted to record these detailed references to the various engineering work done throughout the state as matters for future reference. For this reason I hope that you will pardon the inroads I have made upon your time and patience. In closing, I wish to thank the Society for the honor conferred upon me by electing me to the office of President of this Society. I thoroughly appreciate the honor and express the hope that the Society will continue to prosper and to grow in importance and influence in years to come. I also wish to take this opportunity of thanking all those who have so promptly and cordially contributed the information embodied in this address, including the engineers mentioned herein and others whose names do not appear.

THE RED AND ATCHAFALAYA RIVERS WITH RELATION TO THEIR SEPARATION FROM THE MISSISSIPPI RIVER.

By F. M. Kerr, Member of the Louisiana Engineering Society.

[Read before the Society, December 12, 1910.]

The question of the separation of the Red and Atchafalaya rivers from the Mississippi River appears to me, in many respects, simply one of going back to first principles. In other words, from the best literature on the subject obtainable, and geological and physical evidences in the valley still easily traceable, Red River must at one time have been an independent stream, clearly disassociated with the Mississippi River, neither tributary to it, nor an outlet from it. Characteristic traces of its meanderings along channels wholly removed from the Mississippi River may still be readily followed materially to the west of the Mississippi River.

While tradition, here and there, sometimes links together the Red and Atchafalaya rivers as one and the same stream, the preponderance of opinion leans to the belief that such was never the case. In fact, it is only within comparatively recent times that the Atchafalaya River could be classed as a river at all. The probabilities are that it was, in the beginning, an accident, the development of an overflow coulee, a crevasse or a breach through the west bank of the Mississippi River, during some extraordinary condition of flood in the latter, the overflow racing over the land to the sea by a shorter route than by the main stream.

As an indication of this, it may be noted that the Atchafalaya River in its course *crosses* a number of streams; that is, for every bayou leaving it through its east bank, a similar bayou will be found entering it, almost directly opposite, through its west bank, as though the overflow, in its mad rush to the sea, had jumped bayou after bayou, and cut them in two.

In a little old, time-stained, weather-beaten volume, with accompanying charts, entitled "*The Western Pilot, containing Charts of the Ohio River, and of the Mississippi, from the mouth of the Missouri to the Gulf of Mexico, accompanied with directions for Navigating the same, etc.*," published by Samuel Cumings, in Cincinnati, in 1825, now on file in the office of the Board of State Engineers, occurs the following note and description, viz.:

"Red River, on the right.

"Red River joins the Mississippi a little North of the thirty-first degree of North Lattitude. It is nearly 500 yards wide at its mouth, but its general width is from 250 to 300 yards. The main branch of this noble river has its source in the Mexican Mountains to the Eastward of Santa Fe, about North Lattitude 36°. It runs about 100 miles in a North-east direction, where it unites itself with another large branch from the North-west, then makes a sweep around to the South-east, pursuing this course to the Mississippi, the whole length being nearly 1 500 miles.

"After you have passed Red River, keep nearest the right shore for upwards of six miles, to avoid the bar round the point on the left below, and when nearly up with the right hand point, keep short over for the left shore.

"Bayou Atchafalaya, or Chaffaliar, as it is generally called, is about three miles below Red River, on the right. At high water there is considerable of a draft into the Chaffaliar, which must be guarded against."

This description of the "Chaffaliar Bayou," as therein styled, does not liken it to a river, — at all events not in a class with Red River, — but rather to an overflow coulee, or crevasse. Nor does it appear to confirm any claim that the Red and Atchafalaya rivers were ever one and the same stream. Again, Humphreys and Abbot, in their exhaustive report upon the physics and hydraulics of the Mississippi River, submitted August 5, 1861, in regard to this particular phase of the question, say as follows:

"The opinion has been frequently expressed that Red River was not originally united to the Mississippi, but flowed to the sea separately in the channel now called the Atchafalaya, from which it was disconnected by changes in the course of the Mississippi. This opinion is believed to be erroneous, because the area of the greatest cross-section of the Atchafalaya, at the efflux from the Mississippi, is but little more than half that of the Red River below the junction of Black River, and because the Atchafalaya has not the capacity to discharge much more than half the volume discharged by Red River in flood. If the Atchafalaya had been the channel of Red River, its subsequent connection with the Mississippi could not have diminished its discharge or capacity, since the floods of the Mississippi are of much longer duration than those of Red River, and it is evident, from the very small slope of Red River above its mouth, that its rise and fall at that point could not have been decreased by a junction with the Mississippi.

"The fall per mile of Red River at Alexandria is 0.42 of a foot, and below the junction of Black River only 0.14 of a

foot, while the fall of the Atchafalaya in the first half of its course is 0.64 of a foot per mile.

"It, therefore, appears more probable that the Atchafalaya was a mere valley drain, discharging clear water, until the Mississippi, by eroding its banks, converted it into a waste-weir, when, becoming a muddy stream of increasing discharge, the Atchafalaya began to raise its banks."

In fact, besides these and other similar statements handed down to us in regard to the general characteristics of the Atchafalaya in the past, there are a number of persons still living who will testify that, to their own knowledge, the section of the Atchafalaya was at one time so insignificant that, except during periods of general overflow, it could be safely crossed by simply stepping from log to log, drift heap to drift heap, or "ricket" to "ricket," occupying its channel.

In my own time, I have myself seen the Atchafalaya River, here and there, before it had widened out and deepened to its present proportions, so obstructed with "rickets" — timber projecting up from the bottom, interlaced with drift — as to make it a most dangerous stream to navigate in high water, and to close it against navigation altogether during periods of low water. It, therefore, occurs to me that the statement that the question of the separation of the Red and Atchafalaya rivers from the Mississippi River is, after all, simply one of returning to first principles, is really not unreasonable nor untenable, to say the least.

But let us now shift the scene to comparatively more recent times; to, say, just previous to the occurrence of Shreves Cut-Off, in 1831, which formed what has since been known as Turnbull's Island.

The maps and reports of those days conclusively show that a well-developed river, of goodly proportions and fair regimen known as Red River, *did* enter the Mississippi River from the northwest; and another not so well developed, nor of such goodly proportions, nor fair regimen, *did* depart from the Mississippi River to the southwest, within a very few miles of one another.

This situation, in its relation to Red River, had no doubt come about by the gradual encroachment of the two streams, the Red and the Mississippi, the one upon the other, in the well-recognized easterly and westerly shiftings of their beds, and the final caving of the latter into the former, with the usual ultimate attendant obliteration, as a water way, of the smaller stream, below the junction.

Then, in its relation to the Atchafalaya River, the latter had in the meantime, following a tendency so well developed since, so increased *its* section as to command more attention.

Later on, in 1831, a cut-off occurred across the neck of the bend in the Mississippi between Red River and Atchafalaya River, relegating the two to "Old River," the mouth of the one to the upper part of the concave bend, and the head of the other to the lower part of the concave bend. Then, gradually again, under conditions existing at the time, and for years after, and usually following the life of such conditions, this "Old River" silted up here with sedimentary deposit, and grew up there with timber and brush, until the connection between the Red and Atchafalaya rivers and the Mississippi River became seriously impaired, except during periods of high water, and for years it was only through the most strenuous efforts of the United States, the state, commercial and other interests, that an uncertain and a hazardous connection between the three rivers, by way of the lower reach or arm of "Old River," was at other times, by means of dredging, at all maintained. As for the channel by way of the upper reach or arm of "Old River," it has practically long since become closed even at the higher stages of the Mississippi River.

Despite this, a theory that under certain conditions the Mississippi River would some day or other depart from its present well-defined course to the sea, and take that by way of the Atchafalaya has more than once in the past been seriously and largely advanced and discussed, and lately, with reason, taken on new life.

The premises upon which this possibility was based were as follows, viz.:

(1) The route to the sea by way of the Atchafalaya River is just about one half of that by way of the Mississippi River, the fall, of course, remaining the same. That is, the difference in the elevation of high water at the mouth of "Old River" (Red River Landing), and of Mean Gulf Level at the mouth of the Mississippi River, some 300 miles, is about 30 ft., and at the mouth of the Atchafalaya River, some 160 miles, practically the same. It is, therefore, as you see, reached in just about half the distance by the latter than it is by the former, doubling the rate of fall or slope by way of the latter.

(2) The ever-increasing tendency of the Atchafalaya River itself, irrespective of the conduct of "Old River," to widen and deepen, accentuated by the maintenance and extension of the

levee systems on the east and west banks of the Atchafalaya River.

(3) The possibility at one and the same time of extreme high water in the Mississippi River, and of low water in the Red and Atchafalaya rivers.

However, up to within a comparatively few years this fear was not only not everywhere taken seriously, but gradually allayed by the fact that the enlargement of the Atchafalaya River had been successfully arrested by the United States government, by means of two willow mattress sills weighted with stone, placed across the river about a half a mile apart, near Simmsport; that is, one at Simmsport and the other about a half a mile above.

Then again "Old River" for a long period continued to give every evidence that if left alone it would of its own accord in time silt itself up, wipe itself off of the map, and become a water way only in name. It was, however, only a matter of time when this latter phase of the situation would prove itself a delusion and cease to exist.

This apparent tendency of "Old River" during this period, say, previous to 1897, was, as a matter of fact, due to causes comparatively distantly removed from the locality, namely, the breaching, year after year, of the levee lines in Arkansas and the Fifth Louisiana Levee District, above the mouth of Red River, producing, during certain years, — in fact, *most* years, — overflows in the lower part of the valley of Red River, which added so materially to the volume of water delivered by Red River itself that a state of tentative level, in high water stages, was often enough brought about in "Old River," between the head of the Atchafalaya and the Mississippi, to cause the flow to be at one time from the Mississippi River towards the Red and Atchafalaya, and at another, in the same season, from the Red River towards the Mississippi River. The result, — loss of current in "Old River," the deposit of suspended matter and the silting up of the stream.

But, later on, crevasses in the line of levee described became a thing of the past, the tentative level in the high-water stages at and in the vicinity of "Old River" ceased to occur, and the slope and consequent flow adapted itself at all times, and has done so for several years past, from the Mississippi River towards the Atchafalaya River. Result, — the enlargement, as I am reliably informed, of the section of "Old River" to the extent of something like twenty-five per cent.

Permit this enlargement to proceed, and let that extreme high-water stage in the Mississippi River come along at one and the same time as a period of extreme low water in the Red, and there appears to be much reason to apprehend that other and more extensive sills will become imperative in the Atchafalaya River and that these, even, might in turn fail in the end in stemming the course of such events as were feared in the past, — i. e., the Atchafalaya River becoming the Mississippi River and relegating the present channel of the latter to the secondary position of simply an arm or inlet of the sea.

However, to settle more directly upon the immediate situation and question, let us ask ourselves what is the actual effect of permitting a continuance of the present *status quo* between these rivers?

(1) There is annual overflow to a vast area of land estimated at 1 750 000 acres, at and during every period of high water, and absence of drainage at all times.

(2) No extended and effective relief from these conditions except in the far-away future through measures involving physical contradictions and impracticabilities, beyond the grasp of individuals, corporations, the state or the United States.

(3) Deterioration of the channel of the Mississippi opposite and below the mouth of "Old River," reduction in energy of flow, and higher stages of high water, there and below, with the passage of time.

No one at all familiar with the factors governing the flow of water in sediment-bearing streams, with relation to outlets, such as the connection between the Mississippi River and the Red and Atchafalaya rivers has mostly become, will attempt to refute this. If so, I shall be glad, on some other occasion, when there may be more time, to discuss the question along this particular line.

(4) The possibility, if not probability, at some time or other, probably not distant, of such radical developments in the relations between the streams under consideration, as to cause the Mississippi River to desert its present channel, below the mouth of "Old River," leave the present magnificent section of country from there to the Gulf of Mexico on an arm or inlet of the sea, instead of a mighty river, rob the passes at the mouth of the Mississippi River of their power to maintain themselves, as may be readily conceived, and force the establishment of a new gateway for the valley at the mouth of the Atchafalaya River, with all the necessarily attending disorders.

On the other hand, what does the carrying out of the proposition promise? Improvement in all directions, and the safeguarding of all interests.

And what are the objections that have heretofore been raised against carrying it out?

(1) That it is a scheme for the reclamation of lands.

(2) That it will interfere with navigation between the three rivers.

(3) That it may raise flood levels in the Mississippi River from Natchez to the Gulf, to stages that *might* threaten the integrity of the levee lines.

In regard to the first exception:

For what purpose or aim was the building of levees, and the closing of outlets and crevasses, in the Mississippi Valley, or elsewhere, ever conceived?

For the reclamation of land, and the habitation of the valley.

What better purpose or aim than this can well be conceived?

Is not the reclamation of a million seven hundred and fifty thousand acres of overflowed land, rich in fertility beyond compare, bordering on a network of rivers and bayous and lakes, an advantage for which to seek and strive?

Would not the increased population, the increased wealth, and the increased products consequent upon the reclamation of these lands, and the improvement of river traffic, prove an inestimable advantage?

It certainly appears so to me, and the same thought must have occurred to the legions of those gone by who in the past pinned their faith to similar improvements looking to the reclamation of lands.

In regard to the second exception:

It is not well founded. Provision for the continuance of water connection between the Mississippi River and the Red and Atchafalaya rivers, in the event of the separation of the streams, is already insured in the United States Plaquemines Lock, which is performing its offices with entire success and satisfaction. And, should this lock not prove equal to the demands of the future, the project for the separation of the streams may be made to include another lock in the vicinity of the mouth of Red River, adding, comparatively speaking, but little to the total cost of the proposition.

In regard to the third exception:

It is, in the minds of many, open to serious question whether *any* increase in the height of flood levels, at all events due solely

to confinement at that point, *will* occur, sufficient to menace the levee lines. Some increase *may* at first occur, but certainly not more than can be successfully met in that instance as well as it has been and is being met along all the other miles upon miles of confinement that have already been effected in the valley.

The further building of new lines of levee, the raising and enlarging and maintaining of controlling lines where required, is not going to suddenly cease. Not by any manner of means! The United States, the state and the levee districts of the state are one and all committed to a continuance of work along all these lines, encouraged and fortified by the progress and results already attained.

To support *this* statement, a résumé (marked " Exhibit A ") is submitted, showing the number of cubic yards of levee work built in Louisiana, and that part of Arkansas affecting Louisiana, under each administration, from 1865 to date, by the state, the levee districts, and the United States, aggregating 212 513 762 cu. yd., costing $46 669 111.52, 74 per cent. of which was paid for by the state and levee districts, and 26 per cent. by the United States.

This sum does not include expenses of administration, discounts and interest on bonds, or work not measurable in cubic yards, such as wooden revetments, high-water expenses, crevasse closing, etc., in the past, amounting to several millions in addition.

A further interesting feature of the statement is the progressive activity of the authorities in later years it exhibits, by far the larger part of the effective work having been accomplished since 1882.

If, therefore, you may judge of the future by the past, there certainly does not appear to be any good ground upon which to base any fear that the state will fail to continue to live up to the demands upon her for her levee system.

This brings us to the question of the present preparedness of the lines of levee involved in the proposition. As to this, the facts present a most encouraging state of affairs, which a review will unquestionably establish.

This I will endeavor to present in as concise a way as the subject will permit, by giving you certain extracts from the reply of the Board of State Engineers to a letter of inquiry addressed to it by the Mississippi River Commission, under date of February 21, 1910, taking the liberty of making such free use thereof by reason of the fact that, in my capacity of Chief State Engineer,

EXHIBIT A.

STATE OF LOUISIANA,

OFFICE BOARD OF STATE ENGINEERS,
NEW ORLEANS, November 28, 1910.

Statement showing number of cubic yards of levee work built in Louisiana, and that part of Arkansas affecting Louisiana, under each administration from 1865 to date, by the state, levee districts and the United States, not including expenses of administration, discounts, interest, or work not measurable in cubic yards, such as wooden revetments, high water expenses, crevasse closing, etc.

[*Figures below thousands are omitted.*]

	Years.	Districts.		State.		United States.		Totals.	
		Thousands of Cu. Yd.	Cost, Thousands of Dollars.	Thousands of Cu. Yd.	Cost, Thousands of Dollars.	Thousands of Cu. Yd.	Cost, Thousands of Dollars.	Thousands of Cu. Yd.	Cost, Thousands of Dollars.
Durald Board	1866–1867	....	....	5 121	2 201	....	....	5 121	2 201
Oglesby Board	1867–1868	....	....	1 292	949	....	....	1 292	949
Board of Public Works	1868–1871	....	....	6 012	3 424	....	....	6 012	3 424
Board of State Engineers	1871	....	....	578	329	....	....	578	329
John Lynch, disbursing agent Crevasse Fund	1871	....	....	....	80	....	....	....	80
Louisiana Levee Co. (at 60c. cu. yd.)	1871 to Oct., 1872	....	....	3 586	2 151				
Louisiana Levee Co. (at 50c. cu. yd.)	Oct., 1872, to Oct., 1876	....	....	2 682	1 341	....	....	7 256	3 986
Louisiana Levee Co. (at 50c. cu. yd.)	Oct., 1876, to May, 1877	....	....	987	493				
Gov. F. T. Nicholls	May, 1877–80	....	....	2 484	539	....	....	2 484	539
Govs. Wiltz and McEnery	1880–1884	....	....	5 788	1 414	Not reported	839	5 788	2 253
Gov. S. D. McEnery	1884–1888	2 247	522	6 576	1 336	2 156	736	10 979	2 595
Gov. F. T. Nicholls	1888–1892	10 161	2 133	10 925	1 738	4 872	951	25 959	4 823
Gov. Murphy J. Foster	1892–1896	16 732	2 966	5 447	629	22 591	3 207	44 771	6 803
Gov. Murphy J. Foster	1896–1900	13 604	2 076	4 810	609	15 786	2 402	34 200	5 088
Gov. W. W. Heard	1900–1904	13 299	2 532	4 768	781	8 775	1 294	26 843	4 608
Gov. N. C. Blanchard	1904–1906	4 279	832	3 054	457	4 701	846	12 035	2 136
Gov. N. C. Blanchard	1906–1908	5 774	1 271	2 870	603	3 765	838	12 410	2 713
Gov. J. Y. Sanders	1908–1910	9 217	2 430	3 350	699	4 207	1 003	16 755	4 133
Totals		75 316	14 766	70 340	19 782	66 856	12 120	212 513	46 669

RECAPITULATION.

	Thousands of Cu. Yd.	Cost, Thousands of Dollars.	Per Cent. of Yards.	Per Cent. of Cost.
Total by the state, including Levee District	145 656	34 548	68.5	74.0
Total by the United States	66 856	12 120	31.5	26.0
Excess of State and Levee Districts over United States	78 799	22 428	37.0	48.0

the reply was prepared by me for the Board of State Engineers, by request, and generously concurred in and approved by that body, viz.:

"Little beyond what is herein already said in regard to the effect of the separation of the Red and Atchafalaya rivers from the Mississippi River, from the point of view of riparian property, and of navigation, that might be of service to you, can well be added without going into exhaustive detail, which appears to the Board of State Engineers, under the circumstances, unnecessary. But in regard to its effect, from the point of view of levees, it may be well to review some of the premises advanced, some of the history of high water and the conduct of the lines of public levees in the past, and some facts in regard to their condition at this time.

"Returning, then, to the question of the effect of the proposition on levees, it must be borne in mind that the admissions made by the Board of State Engineers are based upon the assumption that materially increased flood heights *may* follow.

"So, let us review some of the most prominent facts connected with increased flood heights in the Mississippi River in the last fifteen years.

"The committee on levees of your Commission, in 1895, after an elaborate study of the subject, and careful consideration of all the facts involved, reported, among other things, 'That with completed levees, a possible increase of flood heights above the highest heretofore known may occur at the following points and to the following extent:

"'Cairo, 2 ft.; New Madrid, 3 ft.; Memphis, 4 ft.; Helena, 4 ft.; White River, 6 ft.; Vicksburg, 6 ft.; Red River, 5 ft.; Donaldsonville, 3 ft.; Carrollton, 2 ft.; and Fort Jackson, 1 ft.'

"These anticipated increases in flood heights meant the following readings on the gages at the stations named, viz.: Cairo, 54.17; New Madrid, 41.11; Memphis, 39.60; Helena, 52.10; White River, 56.40; Vicksburg, 55.05; Red River, 53.87; Donaldsonville, 33.60; Carrollton, 19.45; and Fort Jackson, 7.9. This estimate of the ultimate increase in flood heights, above the highest previously known at that time, predicated on lines of completed levees, was made when most of the large basins contiguous to the upper part of the valley were still but partially leveed, and, owing to the insufficiency and inadequateness of much of the general levee system below, at that time, crevasses were still frequent and extensive here and there in the Lower Valley.

"Let us, then, now compare the greatest flood heights which have since occurred at the same stations, with all these basins practically leveed and all crevasses closed — except the connections between the Mississippi and the Red and Atchafalaya rivers.

"Cairo, 52.17; or still 2 ft. lower than anticipated; New Madrid, 40.27, or 0.8 lower; Memphis, 40.30, 0.70 higher; White

River, 50.70, or 2.70 lower; Vicksburg, 52.48, or 2.57 lower; Red River Landing, 50.20, or 3.67 lower; Donaldsonville 32.75, or 0.85 lower; Carrollton, 19.42, or 0.03 lower — or practically coinciding; and Fort Jackson, 8.3, or 0.40 higher. It will thus be seen that at ten stations, distributed over more than 1 000 miles of one of the largest rivers in the world, the history of whose floods has attracted the widest attention, this estimate, up to this date, with the levees practically completed, in so far as continuity and successfully opposing past floods, at least, is concerned, has been exceeded but at two stations, Memphis, Tenn., and Fort Jackson, La., by seven tenths and four tenths of a foot, respectively; and is still lower at all the other stations named by margins ranging all the way from about four tenths of a foot to 3.67 ft. — a very decided endorsement of the foresight of your committee and striking evidence of the tendency of the river to gradually regulate itself to such new conditions as confinement, under proper direction and control, may impose.

"It should also be noted in this connection that the greatest departure from this estimated ultimate flood height which has so far occurred is at Red River Landing, still 3.67 ft. below it, just where the first and most serious elevation of flood height resulting from the proposed separation may, if anywhere, be looked for.

"The Board of State Engineers, from this and other assurances, born of extended observation and long experience, is, therefore, disposed to feel that the closure of this one last outlet of the Lower Mississippi River — those immediately above its mouth, of course, excepted — cannot within itself well bring about any material further increase in flood levels that cannot be successfully met by the levee system of the state when completed.

"At all events, this board believes that the question is still sufficiently open not to permit it to seriously weigh against the proposition in advance of the most thorough investigation by competent authority.

"The ultimate flood height, whether resulting solely from the past leveeing in of large basins, closure of crevasses or outlets, or the separation of the Red and Atchafalaya rivers from the Mississippi River, bears such an intimate relation to the second point of view of the effect on levees, namely, increase in and readjustment of grades, that the Board of State Engineers feels it its duty to impose upon your patience somewhat further to touch upon the question of the preparedness of the levee lines that may be affected.

"On the Mississippi River.

"To the construction of the lines of public levee to the provisional grades recommended, from time to time, by the Mississippi River Commission, the efforts of all levee authorities in Louisiana have at all times, as rapidly and as far as their

resources would permit, been faithfully and steadily directed, resulting, at this time, in practically continuous lines of levees in all the levee districts on the Mississippi River, above New Orleans, possessing margins of safety above the highest flood height of record, varying from 2.5 ft. as the least to 6.5 ft. as the greatest.

"At and in the vicinity of New Orleans and below, it is with regret that it must be recorded that the lines of public levee yet vary from as low as a half a foot to 3.5 ft. above the highest flood levels of the past. However, the aggregate lengths of the stretches of levee lines herein referred to as being as low as only half a foot above the highest water of record, is, from New Orleans to the lower ends of the systems on the east and west banks of the river, but about one per cent. of the total length of levee lines between said points.

"Whether, therefore, the separation of the Red and Atchafalaya rivers from the Mississippi River be ultimately brought about or not, vigorous measures are evidently still urgently required to adjust conditions along this part of the Mississippi River — that is, at and in the vicinity and below New Orleans — and the end of levee construction, under any circumstances, is yet far from being in sight.

"To bear out not only this statement, but also that in regard to the present grades of the controlling lines of levee on the Mississippi River, along that part of its length which may be affected, the following, the result of close investigation of the subject, is submitted:

"In Concordia Parish, where the provisional grade recommended by the Mississippi River Commission is, at L'argent (lower end Tensas Parish), 5.5 ft. above the highest water of previous record; at Vidalia, 6.1 ft.; at Bougere, 5.1 ft.; 9 per cent. of the total length of the levee line in the parish (82 miles) is more than 6 ft. above the highest water of record; 40 per cent. from 5 to 6 ft.; 22 per cent. from 4 to 5 ft.; 26 per cent. from 3 to 4 ft., and only 3 per cent. less than 3 ft.; the total number of cubic yards of earthwork still required to adjust this line to this grade being 1 193 000.

"In the Atchafalaya Basin Levee District, from the mouth of Red River, or rather Old River, to Donaldsonville, west bank of the Mississippi River, where the provisional grade recommended by the Mississippi River Commission is 4.3 ft. above the highest water of record at Red River Landing, and 4.2 ft. above at Donaldsonville, 90 per cent. of the 123.8 miles of levee line is from 4 to 5 ft. above the highest water of record; 7 per cent. from 3 to 4 ft., and only 3 per cent. from 2 to 3 ft.; total number of cubic yards of earthwork still required to adjust this line to this grade, only 536 500.

"In the Ponchartrain Levee District, from Baton Rouge to New Orleans, east bank, where the provisional grade recommended by the Mississippi River Commission is 4.6 ft. above the highest water of record at Baton Rouge and 4.0 ft. at the

upper line of Orleans Parish, 88 per cent of the 125.8 miles of the levee line is from 4 to 5 ft. above the highest water of record; 9 per cent. from 3 to 4 ft. above, and only 3 per cent as low as from 2 to 3 ft; total number of cubic yards of earthwork still required to adjust this line to this grade, 394 000.

"In the Lafourche Levee District, from Donaldsonville to New Orleans, and from New Orleans to Riceland Plantation, Plaquemines Parish, west bank, where the provisional grade recommended by the Mississippi River Commission is 4.2 ft. above the highest water of record at Donaldsonville, 4.0 ft. above at New Orleans, and 3.5 ft. at Riceland Plantation, 45 per cent. of the 119.8 miles of the levee line is from 4 to 5 ft. above the highest water of record; 41 per cent. 3 to 4 ft. above; 10 per cent. 2 to 3 ft. above; 3 per cent. 1 to 2 ft. above, and only 1 per cent less than 1 ft. above; total number of cubic yards of earthwork still required to adjust this line to this grade, 520 500.

"In the Orleans Levee District, occupying both banks of the Mississippi River, within the upper and lower limits of the Parish of Orleans, where the provisional grade recommended by the Mississippi River Commission is about 3.4 ft. above the highest water of record, of the 12.23 miles of levee line along the left or east bank, 17 per cent. is from 4 to 5 ft. above the highest water of record; 24 per cent. from 3 to 4 ft. above; 33 per cent. from 2 to 3 ft. above; 9 per cent. from 1 to 2 ft. above; 16.5 per cent from highest water to 1 ft. above, and one half of one per cent. is below high water. Of the 13.63 miles of levee line on the right or west bank, 14 per cent. is from 4 to 5 ft. above; 7 per cent. from 3 to 4 ft. above; 38 per cent. from 2 to 3 ft. above; 36 per cent. from 1 to 2 ft. above, and 5 per cent. from high water to 1 ft. above.

"The number of cubic yards of earthwork required to adjust the lines of levees in the Orleans Levee District to Mississippi River Commission provisional grade is not here presented, because the Orleans Levee District is of record in assuring the Mississippi River Commission that if the United States will handle the problem of bank protection required within the limits of the district, the district will handle the problem of levee construction and maintenance. The yardage required to adjust the levees of the Orleans Levee District to proper grades, etc., should, therefore, not be regarded as a factor in estimating the cost to the United States of the proposition under consideration.

"In this connection, too, it would be well to recall that the Orleans Levee District has inaugurated and is prosecuting levee work on a very large scale, based upon the recommendations of the Board of State Engineers as to grade and section, viz.:

"Grade: 5 ft., net, above the high water of 1903.

"Section: Left bank, crown not less than 50 ft. wide, river side slope not steeper than 3 to 1, and land side slope not steeper than 10 to 1; right bank, crown not less than 10 ft. wide, river side slope not steeper than 3 to 1, and land side slope not steeper than 4 to 1.

"To comply with the foregoing grade and section, it is estimated at this time that as much as 2 189 000 cu. yd. of earthwork will be required for the left bank, and 661 200 cu. yd for the right bank, or a total of 2 850 200 cu. yd.

"In the Lake Borgne Basin Levee District, from New Orleans to the lower line of Bohemia Plantation, Plaquemines Parish, east bank, where the provisional grade recommended by the Mississippi River Commission is 3.4 ft., and 3.0 ft. above the highest water of record at Jackson Barracks and Bohemia Plantation, respectively, 40 per cent. of the 47.9 miles of the levee line is from 3 to 4 ft. above the highest water of record; 32 per cent. 2 to 3 ft. above; 22 per cent. 1 to 2 ft. above; 6 per cent. less than 1 ft. above. Total number of cubic yards required to adjust this line to this grade, about 827 000.

"In the Buras Levee District, from Riceland Plantation to The Jump, Plaquemines Parish, west bank, where the provisional grade recommended by the Mississippi River Commission is 3.0 ft. above the highest water of 1903, at Riceland Plantation, and 3.0 ft. above the highest water of 1907 at Fort Jackson and The Jump, 26 per cent. of the 34.1 miles of the levee line is from 3 to 4 ft. above the highest water of record; 17 per cent. 2 to 3 ft.; 34 per cent. 1 to 2 ft.; and 23 per cent. less than 1 ft. Total number of cubic yards required to adjust this line to this grade, about 429 500.

"In the Grade Prairie Levee District, extending from the lower line of Bohemia Plantation to the lower side of Baptiste Collette Gap, Plaquemines Parish, east bank, where the provisional grade recommended by the Mississippi River Commission is 3.0 ft. above the high water of 1903 at Bohemia Plantation and 3.0 ft. above the high water of 1907 at Fort St. Phillip, 50 per cent. of the 30.1 miles of the levee line is from 3 to 4 ft. above the highest water of record; 27 per cent. 2 to 3 ft. above; 18 per cent. 1 to 2 ft. above, and 5 per cent. less than 1 ft. above. Total number of cubic yards required to adjust this line to this grade, about 230 500.

"The total yardage in Concordia Parish, and in the levee districts herein named, facing the Mississippi River, that may be affected by the proposition to separate the Red and Atchafalaya rivers from the Mississippi River, still required to adjust the grades of the present controlling lines of levee to Mississippi River Commission provisional grade, is, therefore, apparently only about 4 131 000 cu. yd., exclusive of the Orleans Levee District.

"What the difference may be between this amount and that which it may be necessary to add to care for such additional flood height as may be brought about by the separation of the Red and Atchafalaya rivers from the Mississippi River would be difficult for any one to say, as the result must, at this time, be premised upon assumptions still permitting a wide range for speculation.

"The Board of State Engineers, at all events, feels justified

along much stronger grounds in expressing the opinion that, whether the separation of the Red and Atchafalaya rivers from the Mississippi River be ultimately effected or not, higher water may confidently, sooner or later, be looked for on the Lower Mississippi River, and that the separation of the streams in question will little, if at all, aggravate such a situation, and that it, therefore, behooves the levee authorities along this part of the Mississippi River, under any circumstances, to continue to direct their energies towards higher and broader embankments, in making provision for which, that which may be estimated as additionally necessary to guard against any increase in flood levels possibly resulting from the separation of the Red and Atchafalaya rivers from the Mississippi River should not materially disturb them.

"The grounds upon which the Board of State Engineers justifies this opinion in regard to higher flood levels on the lower river, independent of the problem of separation, are based, first, upon the constantly apprehended possibility, if not probability, of a conjunction of extreme high stages of water in a greater number of the main tributaries to the river, if not in all of them, at one and the same time, than in the past; and, second, the failure to so far extend the lines of public levees on the Mississippi River all the way to its mouth.

"From these two elements of disturbance to the regimen of the river, the one, of course, only merely a probability, but the other a self-evident fact, the Lower Mississippi River has, in the opinion of the Board of State Engineers, far more to fear towards higher high waters on the Mississippi River in the future than from the proposition to separate the Red and Atchafalaya rivers from the Mississippi River.

"While it may be true that the steady leveeing of the Mississippi River, throughout its alluvial valley, involving the closure of so many vast basins, which, at first, served as temporary reservoirs for its passing surplus waters, to the exclusion and condemnation of all else in the basin, may have, as already shown, raised, to a material extent, flood levels within the confined limits, it has not followed, in later years, after the beneficial effects of this confinement have been established, that the closure of any one or more additional outlets from the river has in any way seriously aggravated the flood levels then attained.

"In the great overflow years of the past, many crevasses have occurred on the Mississippi River in our state, some of which, in one year and then another, diverted from the main river, at one time and then another, a larger volume of water by far than can well be claimed for the escape from the river, through Old River, and the unleveed stretch between there and Point Breeze, yet there was no hesitation whatever, on the part of all concerned, the following season, or as soon thereafter as the means were provided, in closing each and all of these crevasses or outlets without thought or fear of the results on flood levels in the Mississippi River.

"In evidence of this, not to go back any great length of time, only within the past two years, the great Bougere Crevasse, in Concordia Parish, only about twenty miles above the mouth of Red River, running in high water five miles wide and twenty feet deep, has been closed, and the last two high waters taken care of without outcry reaching the ears or attention of the Board of State Engineers about increased flood levels either in that vicinity or elsewhere.

"In fact, had this bugbear, once so popular among laymen, been, in the past, permitted to sway the activities of the engineers and levee authorities, the state of Louisiana would still be largely in a state of nature — the Paradise of the crocodile.

"On Red River (Lower Red River) and the Atchafalaya River.

"As long as this separation between the Red and Atchafalaya rivers and the Mississippi River be deferred, extensive lines of levees to effectually guard large areas of land, the fertility and productiveness of which when reclaimed cannot well be overestimated, against the injurious influences of floods received from the Mississippi River, will be required along parts of the lower Ouachita River and Black River, and all along the Lower Red River, the Atchafalaya River, Bayou des Glaizes and Bayou Courtableau.

"Such levees as now exist on the Ouachita and Black rivers are fragmentary and far from efficient under almost any condition. On that part of Red River affected, the lines of levees, at the present time, along its right bank, while excellent as far as they extend, still fail to reach the proper lower terminus by over fifty miles, while of the seventy-five miles required on the left bank, only about ten miles have so far been built. On the Atchafalaya River, right bank, of the 100 miles of levee required, but about 37 miles have so far been built; left bank, of the 60 miles of levee practicable at this time, or at any time within the near future, but 43 miles have so far been built. On Bayou des Glaizes, right bank, the system is practically completed; left bank, no part yet undertaken; length of line required, some 50 miles. On Bayou Courtableau, no part of the levee line required on either bank has yet been undertaken; lengths of line required, about 20 miles on each bank.

"Information on which to base anything like a close estimate of the number of cubic yards of earthwork required to improve existing lines of levee along the banks of these streams, and construct the extensions demanded, is not at hand, but, from a general knowledge of the situation, it may be safely said that the yardage required under present controlling conditions will very certainly not fall short of 20 000 000 cu. yd., fully one half of which might be eliminated and dispensed with under the proposition to separate the Red and Atchafalaya rivers from the Mississippi River.

"This, coupled with the reduction of flood heights on Lower Red River and the Atchafalaya River, resulting from the separation of these streams from the Mississippi River, should present a strong appeal in favor of that section of the state which receives no direct aid from the United States in the construction and maintenance of the levee systems required of them.

"Finally, the Board of State Engineers, after weighing all these considerations, is disposed to place itself on record as being in favor of the project as a general proposition, taken up at the proper time and in its proper order. It certainly would appear to be a logical sequence to all that has gone before in the light of river improvement, from both the standpoint of navigation and protection from overflow.

"The Board of State Engineers also desires to express the conviction that the intimate study which the proposition demands has been given into the proper hands, the Mississippi River Commission, and that all interested may rely upon an exhaustive review of all the facts connected with it by the commission, and an impartial, logical and comprehensive conclusion by it."

Since the foregoing statements in regard to the grades and sections of the controlling lines of public levees on the Mississippi River, in Louisiana, were presented, another season of construction and repair has rolled around, and when the contracts for constructing certain new levees, and for enlarging certain others, now in force and in progress, have been completed, most of them before the high water of 1911, history will be found to be but again repeating itself, bringing the line just that much nearer the mark of efficiency and approval as a whole than it was the year previous; and so on and so on, annually, in the future as in the past.

As a practical demonstration of this, a statement (marked "B") — showing the grade of levee lines on the Mississippi River, in Louisiana, exclusive of Orleans Parish, April 16, 1910, compared with the highest water of record, and as it will be found after the completion of the levee work under contract, and in progress for the season 1910–1911 — also accompanies this paper.

Recapitulating this, and translating it into a more direct form, shows that, when the contracts for levee work for this season, now in force and in progress, are completed, most of which will be before the high water of 1911, of the 721 miles of levee lines in Louisiana, on the Mississippi River, at present controlling overflows, exclusive of the Orleans Levee District, 521.6 miles will have already been constructed to the provisional

EXHIBIT B.

Statement showing the grade of levee lines on the Mississippi River, in Louisiana, exclusive of Orleans Parish, April 16, 1910, compared with highest water of record, and as it will be found after the completion of the levee work under contract, and in progress for the season of 1910–1911.

	Feet above Highest Water.							M. R. C. Provisional Grade above High Water.
	0 to 1 Feet.	1 to 2 Feet.	2 to 3 Feet.	3 to 4 Feet.	4 to 5 Feet.	5 to 6 Feet.	6+ Feet.	
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	
Fifth Louisiana Levee District.				*Condition April 16, 1910.*				
East Carroll Parish		....	13.3	13.2	20.4	....	....	
Madison Parish		1.8	13.0	11.4	16.4	....	....	4.0 ft.
Tensas Parish		....	13.0	15.0	7.4	23.6	....	5.0 ft., Bedford; 5.5 ft., L'argent.
Concordia Parish		....	2.7	21.6	17.9	32.6	7.2	6.2 ft., Vidalia; 5.0 ft., Bougere.
Total miles		1.8	42.0	61.2	71.1	50.2	7.2	
				Condition after Completion of Contracts in Force.				
East Carroll Parish			1.3	9.0	45.7	....	....	
Madison Parish			7.8	11.2	23.7	....	....	
Tensas Parish			2.4	7.3	6.6	42.7	....	
Concordia Parish			3.2	14.2	17.9	33.0	14.5	
Total miles			14.7	41.7	93.9	75.7	14.5	
Atchafalaya Basin Levee District.				*Condition April 16, 1910.*				
Pointe Coupee Parish			2.0	0.8	46.7			
West Baton Rouge Parish			0.3	3.1	33.2	....	....	4.4 ft. at Red River Landing.
Iberville Parish			0.9	....	26.5	....	....	4.6 ft. at Port Allen.
Ascension Parish			1.2	4.7	4.4	....	....	4.2 ft. at Donaldsonville.
Total miles			4.4	8.6	110.8			
				Condition after Completion of Contracts in Force.				
Pointe Coupee Parish			2.0	0.5	47.0			
West Baton Rouge Parish			0.3	3.1	33.2			
Iberville Parish			0.9	....	26.5			
Ascension Parish			0.3	3.9	6.1			
Total miles			3.5	7.5	112.8			

PONCHARTRAIN LEVEE DISTRICT.			*Condition April 16, 1910.*					
East Baton Rouge Parish			0.1	2.3	11.6			
Iberville Parish			....	0.6	26.1			
Ascension Parish			0.2	0.1	18.8	....	....	4.6 ft. at Baton Rouge.
St. James Parish			....	....	23.3	....	....	4.0 ft. at Orleans Parish, upper line.
St. John Parish			2.3	....	12.4			
St. Charles Parish			1.2	....	15.3			
Jefferson Parish			0.3	7.9	3.3			
Total miles			4.1	10.9	110.8			
			Condition after Completion of Contracts in Force.					
East Baton Rouge Parish			0.1	2.3	11.6	....		
Iberville Parish			....	....	25.2	1.5		
Ascension Parish			0.2	0.1	18.8	....		
St. James Parish			....	....	23.3	....		
St. John Parish			....	....	14.7	....		
St. Charles Parish			....	....	16.5	....		
Jefferson Parish			0.1	7.9	3.5	....		
Total miles			0.4	10.3	113.6	1.5		
LAFOURCHE LEVEE DISTRICT.			*Condition April 16, 1910.*					
Ascension Parish	....	....	0.9	0.1	6.4			
St. James Parish	....	....	0.1	0.1	21.5	....	....	4.2 ft. at Donaldsonville.
St. John Parish	....	....	0.5	0.1	14.3	....	....	4.0 ft. at Orleans Parish, upper line.
St. Charles Parish	....	....	2.4	8.1	7.4	....	....	3.3 ft. at Riceland Plantation.
Jefferson Parish	....	1.2	2.1	11.8	4.9			
Plaquemines Parish	1.1	2.3	5.8	28.7	....			
Total miles	1.1	3.5	11.8	48.9	54.5			
			Condition after Completion of Contracts in Force.					
Ascension Parish	....	....	....	....	7.4			
St. James Parish	....	....	0.1	0.1	21.5			
St. John Parish	....	....	0.5	0.1	14.3			
St. Charles Parish	....	....	2.4	7.9	7.6			
Jefferson Parish	....	1.1	2.1	11.8	5.0			
Plaquemines Parish	0.8	2.3	5.3	29.5	....			
Total miles	0.8	3.4	9.4	49.4	55.8			

EXHIBIT B.—*Continued.*

	Feet above Highest Water.							M. R. C. Provisional Grade above High Water.
	0 to 1 Feet.	1 to 2 Feet.	2 to 3 Feet.	3 to 4 Feet.	4 to 5 Feet.	5 to 6 Feet.	6+ Feet.	
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	
Lake Borgne Basin Levee District.	*Condition April 16, 1910.*							
St. Bernard Parish	....	2.4	4.3	4.1	....	....	....	3.6 ft. Orleans Parish, lower line.
Plaquemines Parish	3.0	8.1	11.0	15.0	....	....	....	3.3 ft. Bohemia Plantation.
Total miles	3.0	10.5	15.3	19.1				
	Condition after Completion of Contracts in Force.							
St. Bernard Parish	....	2.4	4.3	4.1				
Plaquemines Parish	2.2	7.5	8.5	18.9				
Total miles	2.2	9.9	12.8	23.0				
Buras Levee District.	*Condition April 16, 1910.*							
Plaquemines Parish (right bank)	7.9	11.5	5.8	8.9	....	....	....	3.3 ft. at Riceland Plantation. 3.0 ft. at Fort Jackson. 3.0 ft. at "The Jump."
	Condition after Completion of Contracts in Force.							
Plaquemines Parish (right bank)	7.6	11.4	5.8	9.3				
Grand Prairie Levee District (left bank).	*Condition April 16, 1910.*							
Plaquemines Parish (left bank)	1.6	5.4	7.9	15.2	....	....	....	3.3 ft. at Bohemia Plantation. 3.0 ft. at New Canal.
	Condition after Completion of Contracts in Force.							
Plaquemines Parish (left bank)	1.6	4.1	7.9	16.5				

RECAPITULATION BY DISTRICTS.

	Feet above Highest Water.						
	0 to 1 Feet.	1 to 2 Feet.	2 to 3 Feet.	3 to 4 Feet.	4 to 5 Feet.	5 to 6 Feet.	6+ Feet.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
	Condition April 16, 1910.						
Fifth Louisiana Levee District	....	1.8	42.0	61.2	71.1	56.2	7.2
Atchafalaya Basin Levee District	....	....	4.4	8.6	110.8	....	....
Ponchartrain Levee District	....	....	4.1	10.9	110.8	....	....
Lafourche Levee District	1.1	3.5	11.8	48.9	54.5	....	....
Lake Borgne Basin Levee District	3.0	10.5	15.3	19.1	....	....	....
Buras Levee District	7.9	11.5	5.8	8.9	....	....	....
Grand Prairie Levee District	1.6	5.4	7.9	15.2	....	....	....
Total miles	13.6	32.7	91.3	172.9	347.1	56.2	7.2
	Condition after Completion of Contracts in Force.						
Fifth Louisiana Levee District	....	....	14.7	41.7	93.9	75.7	14.5
Atchafalaya Basin Levee District	....	....	3.5	7.5	112.8	....	....
Ponchartrain Levee District	....	....	0.4	10.3	113.6	1.5	....
Lafourche Levee District	0.8	3.4	9.4	49.4	55.8	....	....
Lake Borgne Basin Levee District	2.2	9.9	12.8	23.0	....	....	....
Buras Levee District	7.6	11.4	5.8	9.3	....	....	....
Grand Prairie Levee District	1.6	4.1	7.9	16.5	....	....	....
Total miles	12.2	28.8	54.5	157.7	376.1	77.2	14.5

RECAPITULATION SHOWING LENGTHS IN MILES AND PERCENTAGES OF LEVEE LINES CONSTRUCTED TO MISSISSIPPI RIVER COMMISSION PROVISIONAL GRADE, AND OTHER GRADES COMPARED WITH HIGHEST WATER OF RECORD.

	M. R. C. Provisional Grade and +.	Feet above Highest Water.				
		4 to 5 Feet.	3 to 4 Feet.	2 to 3 Feet.	1 to 2 Feet.	0 to 1 Feet.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
Fifth Louisiana Levee District	159.6	24.5	41.7	14.7	....	....
Atchafalaya Basin Levee District	112.8	....	7.5	3.5	....	....
Ponchartrain Levee District	115.1	....	10.3	0.4	....	....
Lafourche Levee District	85.3	....	19.9	9.4	3.4	0.8
Lake Borgne Basin Levee District	23.0	....	....	12.8	9.9	2.2
Buras Levee District	9.3	....	....	5.8	11.4	7.6
Grand Prairie Levee District	16.5	....	....	7.9	4.1	1.6
Total	521.6	24.5	79.4	54.5	28.8	12.2
Total length, 721 miles.						
Reduced to percentages	73%	3%	11%	7%	4%	2%

grade recommended by the Mississippi River Commission, and *above;* 24.5 miles will be not less than from 4 to 5 ft. above the highest water of record, locally; 79.4 miles, 3 to 4 ft. above; 54.5 miles, 2 to 3 ft. above; 28.8 miles, 1 to 2 ft.; and only 12.2 miles as low as from high water to 1 ft. above, the latter largely upon what is known as the Lower Coast (Buras and Grand Prairie Settlements).

However, after all may be said, the most encouraging feature of the present consideration of the subject is the fact that an elaborate and exhaustive study of the whole subject is now being made by the Mississippi River Commission, and it is my earnest belief that we can all, with confidence, well afford to await the report of that most able and distinguished body for more definite information and enlightenment in regard to it.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 15, 1911. for publication in a subsequent number of the JOURNAL.]

THE WATER STORAGE SYSTEMS OF UTAH, PRESENT AND PROSPECTIVE.

By H. S. Kleinschmidt, Member of the Utah Society of Engineers.

[Read before the Society, November 19, 1910.]

Reservoirs for storing water in connection with irrigation and power projects are becoming increasingly important and necessary, not only in Utah, but in all the arid and semi-arid states.

The need for reservoirs is chiefly due to the character of our streams, most of them showing wide extremes of flow, — in the spring discharging torrents, and in the summer, when water is most needed, being often entirely dry.

For many years subsequent to the settling of Utah by the pioneers, the flow of the streams was at all times sufficient for the needs of the people. In time, however, the area brought under cultivation was increased beyond the duty of the streams during periods of unusual drought, and it became necessary to resort to the construction of reservoirs, in which the surplus flow during the non-irrigation season or times of freshet could be held and made use of when needed.

Utah is the pioneer of irrigation in the United States, and while there is much room for improvement on the old, and the development of new projects, she has reason to be proud of the success thus far attained.

For the benefit of a possible few who may not be familiar with this matter, I will define the standards of measure for water used in irrigation and power developments. The standard unit for stored water is the acre-foot, one acre-foot meaning a depth of one foot over an area of one acre. The standard unit for flowing water is the second-foot, one second-foot meaning a flow of one cubic foot of water per second of time passing a given point. One second-foot flowing continuously for twenty-four hours is equivalent to two acre-feet. These units of measure have been universally adopted, and most states define by law that these are the legal units of measure.

Aside from natural lakes and depressions which were easily converted into storage basins, practically all the reservoirs in Utah have been formed in the channels of the streams, by damming at a narrow point in the eroded channel, where the topog-

raphy above the dam site is such as to afford an economical storage basin.

In point of magnitude and labor expended, most of our modern irrigation works sink into insignificance when compared with those of the ancients, especially in India and other far eastern countries. Under present economic conditions such achievements would be impossible.

By far the largest reservoir in the state is Utah Lake, in Utah County. The majority of persons perhaps do not know that it is a reservoir. However, were it not for the controlling works at the outlet of the lake into the Jordan River, the canals heading in the Jordan River, which water collectively one of the largest areas in the state, would suffer almost yearly from lack of water. These controlling works consist of a dam across the channel of the Jordan River, with a number of gates of the ordinary head-gate type, by means of which the outflow from the lake may be regulated as desired, except during seasons of extreme high water.

Utah Lake receives the drainage from an area of approximately 3 600 sq. miles, a large part being mountainous, and reaching to altitudes of 12 000 ft. At "compromise level," which is the level at which the courts have ruled that the holding back of water so far as effected by the controlling works, must stop in order not to flood adjacent land, the lake has an area of 93 000 acres, or about 160 sq. miles, and a capacity of 825 000 acre-feet. During years of normal precipitation the lake may be expected to reach this level, and during the three years previous to 1910, which were years of excessive precipitation, in spite of court decree and the removal of all regulating gates, the lake persisted in remaining above compromise level for nearly the entire period, flooding many thousands of acres bordering the lake. In 1901, during the excessively dry period lasting from 1900 to 1905, it became necessary to install a battery of pumps to raise water from the lake into Jordan River, the lake level having fallen below the bottom of the outlet channel. This pumping plant was used for several years in succession, and is held in readiness for use at any time. There are five centrifugal pumps, electrically driven, and rated at 100 sec. ft. each (see U. S. Exper. Sta. Bul. 124). There are five principal canals that obtain their water supply from the lake, and in addition numerous small ditches. Also one hydro-electric plant in the Jordan Narrows with several smaller power installations. The canals water an area of about 50 000 acres.

Another great natural reservoir is Bear Lake, lying half in Idaho and half in Rich County, Utah. This, together with further mention of Utah Lake, will be found under the head of Future Possibilities.

The principal river systems of the state are: Bear River with its main tributaries, the Logan and Blacksmith Fork rivers; the Ogden and Weber rivers in the northern part of the state; the Utah Lake-Jordan River system, embracing numerous streams issuing from the Wasatch Mountains from Salt Lake City south to Santaquin, all in the Great Basin, in the north-central part of the state; the DuChesne River and tributaries, which is a part of the Green-Grand-Colorado River system, the other principal tributaries of which are, from north to south, the Price, San Rafael, Fremont, Escalante and San Juan rivers, this system draining the entire eastern half of the state into the Colorado River; the Sevier River system, with numerous tributaries draining a large part of the state in the south-central, central and western part, in the Great Basin; and the Virgin River in the extreme southwest, tributary to the Colorado River.

The Sevier River is the most completely controlled large stream in the state. It presents many interesting features, about which a good-sized volume might well be written, and only a brief outline of the developments on this stream will be given here. It consists of two main branches, South Fork and East Fork, both rising in the mountains about forty miles north of the Arizona line, and paralleling each other north for sixty miles to their junction in Piute County, separated by a mountain chain, and never more than twenty miles apart. From this junction, the river flows north and easterly seventy-five miles to near Gunnison in Sanpete County, where it is joined by the San Pitch River, flowing from the north, having its source near the center of the state. From Gunnison it flows northwesterly thirty miles, turns the point of the Pavant Range near Juab, and flows southwesterly sixty miles and discharges into Sevier Lake, a brackish body of water with no outlet. The Sevier River is characterized throughout its entire length by numerous admirable reservoir sites, formed by broad river bottoms, with narrow gorges for dam sites, where the stream has cut its way through spur ridges from the main mountain chains.

Near the head of South Fork in Garfield County, the State Land Board has recently completed the Hatchtown Reservoir. The dam is built between a basalt cliff and a clay and gravel hill. It is an earth fill 64 ft. high, containing 135 000 cu. yd.

The upper slope is riprapped with basalt bowlders. Junction with the impervious clay substratum under the dam was made by an open trench in which a row of timber sheet piling was driven, upper ends projecting into the clay puddle core. Outlet tunnel is of masonry, built in the stream bed, regulating gates, two in number, being set in a heavy reinforced concrete chamber and operated from the top of a masonry tower or well in the center of the dam. The area of the reservoir at full stage is 500 acres and capacity 13 200 acre-ft. The stored water will be used to reclaim about 6 000 acres of land lying near Panguitch, twenty-five miles north of the reservoir. The canal and other works have been completed, the total cost of the project being $150 000.

On East Fork the largest reservoir is the Otter Creek, just above the junction of the two main branches of East Fork, near Coyoto. It has a capacity of about 50 000 acre-ft. The dam is an earth fill about 50 ft. high. Ordinarily it entirely controls the flow of Otter Creek, and the supply for storage is usually supplemented from East Fork by a canal. This is one of the first large reservoirs built in the state, and it still ranks among the largest. The stored water is allowed to flow down the Sevier River a distance of sixty miles, where it is diverted at the head of Sevier Valley and used to irrigate land between Joseph City and Richfield.

Twenty-five miles below Otter Creek reservoir, at the junction of East and South Forks, the State Land Board is now building a large reservoir. An earth dam 90 ft. high, 800 ft. long on top, and containing 250 000 cu. yd. will form a storage basin $6\frac{1}{2}$ miles long, with an area of 2 200 acres and a capacity of 88 000 acre-ft. The outlet tunnel, 7 ft. by 9 ft., 475 ft. long, has been built in solid rock, and serves to carry the flow of the river during the construction of the dam. The regulating gates, three in number, 4 ft. square, of cast iron, slide on massive bronze and steel bearings, set in a heavy concrete heading at the upper end of the tunnel. Guides for the gate stems are anchored to the solid rock cliffs that rise almost vertically above, the gates being operated by ball-bearing geared hand wheels set on a platform anchored to the cliffs. Spillway will be part in rock and the remainder in concrete. The dam will be founded on bedrock, which is covered to an average depth of 30 ft. with gravel and sand and bowlders. This was determined by a row of 6-in. wash boring and churn drill wells along the axis of the dam. A core trench 15 ft. wide on the bottom, 25 ft. wide on

top, has been excavated to bed rock. In this a concrete junction wall will be built, and the trench backfilled with clay and gravel puddle, which will be carried up nearly to the top of the dam. The upper toe has been built to an elevation of about 50 ft. by wagon and wheel scrapers. The remainder of the fill will be made by the hydraulic method. A sluicing plant is now being installed, consisting of about 3 miles of wood stave pipe, 16 in. and 12 in. in diameter, two giants operating under a head of 400 ft., and half to three quarters of a mile of carrying and distributing flume, lined with special rolled steel plates, on account of the excessive scour by the sluiced material. The amount of water available for sluicing varies from 1.5 to 10 sec.-ft. and will be conveyed to the dam site under the working head from several small streams by gravity. The material available is of a rather sandy character, but sufficient clay has been developed to insure a proper mixture for a dam of this type. The work is being done under the direction of state engineer Caleb Tanner and Joseph Jenson, constructing engineer. This work is being watched with interest, as it is the first large fill to be made by the hydraulic method in this state. The stored water will be allowed to flow down the Sevier River, and will be diverted through the same canal as the Otter Creek Reservoir water. This canal has been enlarged from a maximum capacity of 80 sec.-ft. to 400 sec.-ft. and extended twenty miles beyond its old terminus at Richfield. Another twenty miles of canal will be built, extending it to beyond Gunnison, making the main canal nearly 60 miles long. The project, when completed, will reclaim about 22 000 acres. Surveys and preliminary construction at the dam site, and surveys and construction of the canal, were done under the direction of the writer.

Ten miles northeast of Gunnison, on the San Pitch River, is the Gunnison Reservoir. It has a capacity of about 23 000 acre-ft. The dam is an earth fill, about 40 ft. high, 1 200 ft. long on top. In years of normal run-off this reservoir completely controls the flow of the San Pitch River. The stored water is used on land surrounding Gunnison.

The next important reservoir on the Sevier River is the Sevier Bridge or Deseret Reservoir. It has a capacity of 90 000 acre-ft. The impounding dam is an earth fill 70 ft. high, 660 ft. long on top.

The Gunnison Bend Reservoir is some twenty-five miles down the river. It has a capacity of 15 000 acre-ft. The dam is an earth fill 25 ft. high.

This completes the list of the principal reservoirs on the Sevier River.

Passing now to the extreme southwestern part of the state, there is one project there of considerable magnitude and interest. A reservoir is being built in Grass Valley, in the drainage of the Virgin River. The dam is an earth fill, and when complete will be 110 ft. high. It will create a storage capacity of 30 000 acre-ft. Water to supply this will be in part diverted by canal from small streams outside its drainage. The stored water will be taken from the reservoir by a tunnel about $\frac{1}{2}$ mile long, out of the Virgin River drainage into the Great Basin and used to reclaim land on the Modena Desert about twenty miles east of Modena.

The only United States Reclamation Service project under way in this state is the Strawberry Valley project. The reservoir site is located at the lower end of Strawberry Valley, at an altitude of 7 500 ft., 30 miles due east of Provo, and in the Colorado River drainage system. A dam 60 ft. high and 400 ft. long on top will form a reservoir with a capacity of 290 000 acre-ft. So far as known to the writer, this is the most economical site in the state. The average annual discharge at the dam site is about 60 000 acre-ft., based, however, on rather incomplete records, and during years of less than normal run-off. During years of high water the run-off reaches 150 000 acre-ft. On account of the large variation in its annual run-off from the area tributary to the reservoir, it is deemed advisable to construct the reservoir large enough to hold any possible run-off. It is also possible to divert water by canal from streams outside the reservoir. Water will be drawn from the reservoir by means of a tunnel 19 500 ft. long, concrete lined throughout, discharging into Diamond Fork of Spanish Fork River. It will be diverted, together with the flow of Spanish Fork, near Castilla in Spanish Fork Canyon, and carried a distance of about three miles by concrete-lined canal and tunnel. As much as will be needed to supply the present system will then be dropped through a hydro-electric power plant. The remainder will be carried by high line canal through Payson, Santaquin and around the extreme southern end of Utah Valley. The project will reclaim and furnish additional water to about 60 000 acres. To date, about 10 000 ft. of tunnel has been driven at the rate of 400 to 500 ft. per month. The power canal and power house have been in operation for about two years, power being transmitted about

thirty miles for use at the tunnel workings. The cost of the project will be about $2 500 000.

In the northwest part of Juab County the Mt. Nebo Reservoir completely controls the flow of Currant Creek. Its capacity is given as about 30 000 acre-ft.

On the Price River, flowing east from the central part of the state, there have been no reservoirs of any size constructed to date. One, the Mammoth, has been partly built. It lies on Gooseberry Greek, tributary to Price River, about 12 miles west of Scofield, in San Pete County. When complete, the reservoir dam, an earth fill, with reinforced concrete core wall 1.5 ft. thick, will be 100 ft. high, 500 ft. long on top, making a storage capacity of 26 000 acre-ft. The intention of the originators of the project was to use the water along the Price River in the vicinity of Price. It has also been considered to divert the water by tunnel into the drainage of the Sevier River.

The only other reservoir of any size in the state is the East Canyon Creek reservoir in East Canyon, tributary to the Weber River, in the northern part of the state. The dam is a rock-fill structure with a steel core anchored to a concrete base founded on bed rock, and faced on both sides with asphalt concrete, 4 in. thick. The steel core varies from 5/16 in. at the bottom to 3/16 in. at the top. The dam was built by blasting down the sides of the canyon above the top of the dam, the material thrown down being allowed to remain as it fell. A cut was then made in this fill down to the previously constructed concrete base, and the steel plate and backing built, the rock being hand laid in the trench. The dam was raised from its original height of 68 ft. to 93 ft., the steel core being carried up on the upper face of the raised portion which was given a slope of 30 degrees from the vertical. The capacity of the reservoir is about 10 000 acre-ft. and in spite of the high cost per acre-foot of water stored, the land on which the water is used is so productive that it has been one of the best paying projects in the state, and illustrates the fact that in favored localities the cost of storing water may be put at a seemingly prohibitive figure.

This completes the list of the principal storage systems of the state. On nearly all the streams are found numerous small units, the aggregate capacity of which is large, but which individually may be neglected as having any measurable influence on the flow of the streams, but which, however, make possible the cultivation of a large number of small areas.

Future Possibilities.

The possibilities for expansion and improvement in the future of the existing reservoir systems, and the development of new ones, hold much promise. Excepting on the Sevier River on which the storage has about reached its full development, all our principal streams discharge enormous volumes of water during high water periods, from most of which no direct benefit is derived, and which on most streams is many times the amount utilized. The unused discharge from some of the principal streams is:

Bear River at Collinston,	1 600 000	ac.-ft.	per	annum
Weber River at Plain City,	800 000	,,	,,	,,
Price River at Woodside,	250 000	,,	,,	,,
San Rafael River near Green River,	275 000	,,	,,	,,
Green River at Green River,	5 500 000	,,	,,	,,
Fremont River at Thurber,	125 000	,,	,,	,,
Escalante River at Escalante,	50 000	,,	,,	,,

All but the first two of these are in the eastern part of the state, a comparatively unexploited region, so far as large reclamation enterprises are concerned. On most of these the problems of storage and usage are difficult, and it is very doubtful if anything like entire control will ever be attained. The main reasons are that the streams carry excessive amounts of silt, menacing the life of reservoirs, and usually lie in quite deep canyons, making the cost of recovery and distribution on to irrigable areas prohibitive under present conditions. However, we may confidently expect to see a considerable development within the next few years. Numerous projects have been investigated and the merits of some are so evident that they will without doubt be undertaken. Among these are the following "Carey Act Projects":

Woodside Project on the Price River, to irrigate from 6 000 to 25 000 acres.

Buckhorn Project on the San Rafael River, to irrigate 23 000 acres.

Green River Project on Green River, to irrigate 200 000 acres near Green River.

Two others on which no definite plans have matured are on the Fremont and Escalante rivers.

On the Fremont River at Thurber, there is a site capable of holding the entire discharge of the river, amounting to about 125 000 acre-ft. per annum. The site is a very favorable one.

In the DuChesne River Basin in the northeastern part of the state, developments to the present have depended on the natural flow of the streams. The topography of the region is in general such that there are but few large economical reservoir sites.

On the Weber and Bear rivers the problems of storage are different from those in the eastern part of the state. The silt problem is a minor one, as is that of getting water from the streams on to the arable areas. But the reservoir sites as a rule are not highly favorable, and in the case of the Weber River the small valleys that would form the reservoirs are occupied by farms and towns, railroads and other industries. The development of these sites depends on whether the value of the water available will ever become greater than the cost of construction plus the value of the farms, etc., which the reservoirs would displace.

On Bear River several sites have been investigated and found feasible. These lie mostly on the headwaters in Wyoming. Among these are the Narrow Site near Evanston,—a dam 125 ft. high, 875 ft. long on top, would create a storage capacity of 233 000 acre-ft.; Yellow Creek Site, a dam 130 ft. high, 1 300 ft. long on top, capacity 44 000 acre-ft., Coyote Site, dam 120 ft. high, 660 ft. long on top, capacity 40 000 acre-ft. Bear Lake, lying half in Idaho and half in Rich County, Utah, presents great possibilities. This was investigated by the United States Reclamation Service. It was estimated that an annual supply of 350 000 acre-ft. could be had from the surplus flow of Bear River, which could be diverted into Bear Lake for storage by a canal eight miles long. The large number of private claims involved led the Reclamation Service officials to abandon this project, and the original plans are now being carried out in part by private enterprise.

Turning again to Utah Lake, we find a waste of water there that is regrettable, to say the least. As before stated, the capacity of the lake at compromise level is 825 000 acre-ft. The United States Reclamation Service investigated this project in 1903–1905 (see 2d, 3d and 4th annual reports), the conclusions in brief being: That the average annual measured and unmeasurable (underground springs and seepage) inflow to the lake was 525 000 acre-ft. This estimate was based on the supply during a series of years of less than normal run-off. That the loss by evaporation from the lake surface was 470 000 acre-ft. per year, or a depth of over 5 ft. That a supply of at least 300 000 acre-ft.

could be drawn from the lake during a 5-month irrigation season, or at the rate of 1 000 sec.-ft., sufficient to serve 100 000 acres, as compared to not over 50 000 acres now watered. Here, as in the case of Bear Lake, the many and varying private interests led to the abandoning of the project. The unfailing water supply, and the location of the project in one of the most favorable regions in the state from every standpoint, would seem to make the development of the project a certainty. There has been considerable activity of late along the lines of pumping water from Utah Lake on to bench lands on the west side of the lake. One undertaking, the Moseda Project, involves the raising of water to a maximum elevation of 160 ft. to irrigate 6 000 acres.

On the Sevier River, future developments will be mainly along the lines of improving the existing systems, by consolidating and lining canals, to eliminate excessive seepage losses, and the enlargment of existing reservoirs. As now built or under construction these will in years of average run-off completely control the flow of the river. However, years of excessive run-off occur at frequent intervals, and by increasing the capacity of the reservoirs it will be possible to store the entire flow and hold it over for years of less than normal supply, and by proper coöperation between the various reservoir and irrigation companies to bring large additional areas under cultivation. One notable possibility of increasing the capacity is the Sevier Bridge Reservoir, it being feasible to increase its capacity from about 90 000 acre-ft. to perhaps 300 000 acre-ft.

The Virgin River in the extreme southwestern part of the state presents probably as great possibilities as any stream in the state. There is a large surplus flow in the spring, and during summer cloudburst period the streams are subject to violent floods. The fact that the river carries a very high percentage of silt, mostly fine sand, makes reservoirs on the lower portions of the Virgin River subject to excessive silting. Several sites have been investigated, those on the headwaters by the writer. These are small, ranging from 5 000 to 20 000 acre-ft. On the lower reaches are several sites of from 200 000 to 300 000 acre-ft. capacity and more. These involve very large structures, and the cost per acre would be very high. Owing to the climatic conditions of the region, however, the excessive cost is permissible in view of the large returns that can be expected. The region drained by the Virgin River is for the most part one of extremely broken topography, due mainly to the comparatively

recent seismic and volcanic activity that has taken place. This, together with the action of the elements on the soft sandstone, which predominates over the entire region, has made it a veritable topsy-turvy land. The lack of transportation facilities has been the drag anchor of extensive developments here, there being no incentive for production beyond the local demand.

This in brief is a summary of the existing reservoir systems, and the principal possibilities. There are doubtless many projects worthy of mention that have escaped the writer's notice, and no doubt from time to time with the increase in the value of land and water, new projects will be undertaken, which have failed to attract favorable attention to the present.

The improvement in the physical condition of existing systems which has already been actively undertaken, the improvement in the methods of distribution of water, as well as the more national and economical use thereof by the irrigators will go hand in hand in the future with the development of new systems to share in the bringing of increased areas of now barren land to a condition of high productiveness.

Those who may be interested in a further study of this matter are referred to the following publications:

United States Reclamation Service Annual Reports.

United States Department of Agriculture Bulletin No. 24, entitled "Irrigation Investigations in Utah."

Biennial Reports of the State Engineer to the Governor of Utah.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 15, 1911, for publication in a subsequent number of the JOURNAL.]

METHOD OF ESTIMATING THE PROBABLE VOLUME OF RAILWAY TRAFFIC.

By George Rathjens, Member of the Civil Engineers' Society of St. Paul.

[Read before the Society, January 9, 1911.]

In considering large economic problems pertaining to the betterment of railway properties and to the inception, projection and financing of new projects, the question, What will be the probable volume of traffic? usually presents itself. To determine the volume of traffic with exactness is, of course, impossible; but by a study of past experience a fairly accurate estimate may be made. As our best guide is the statistics of the past, the author has compiled statistics and has endeavored to put them into such form that they could be used in making an estimate of the traffic to be expected from any given territory whose commercial and social conditions were similar to those of the area from which the statistics were derived.

It is the purpose of the author to explain how such statistics may be used in estimating the probable traffic in a given territory at any given time.

For the purpose of this investigation it is necessary to express in mathematical terms the relation between tonnage and the population. It is well known that of all the mathematical curves the parabola is the most flexible and also has the most simple equation. For this reason the author chooses the parabola having the equation $X = K\,Y^{\triangle}$, in which X represents the tonnage and Y the population, K is a constant, and $\triangle$ is an exponent to be determined. In discussions of this character the data can be presented more clearly graphically than otherwise; and, therefore, the graph of the above equation will be used to represent the relation between the amount of traffic and the population. It remains, then, to determine the value of the constant K and of the exponent $\triangle$.

It is a well-known fact that the equation $X = K\,Y^{\triangle}$ can be represented by a straight line on logarithmic paper, that is, paper divided so that the divisions are proportional to the logarithm of the number; and also that the slope of this line determines the value of $\triangle$. The intersection of this line with

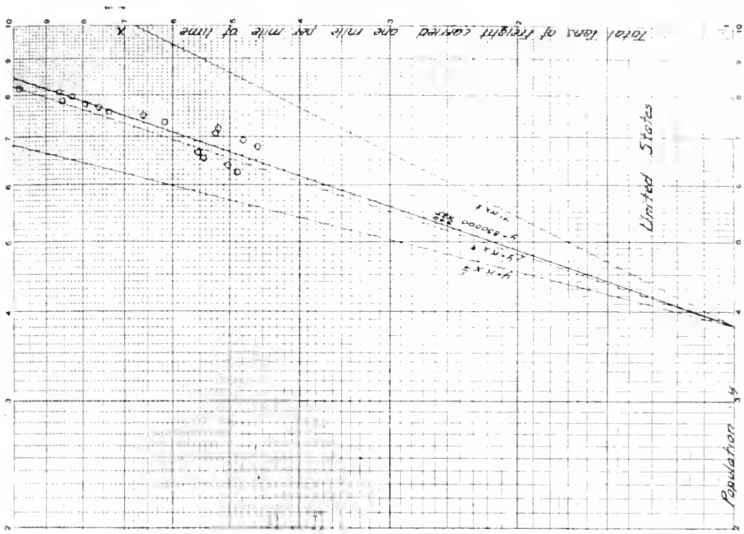


Plate 2

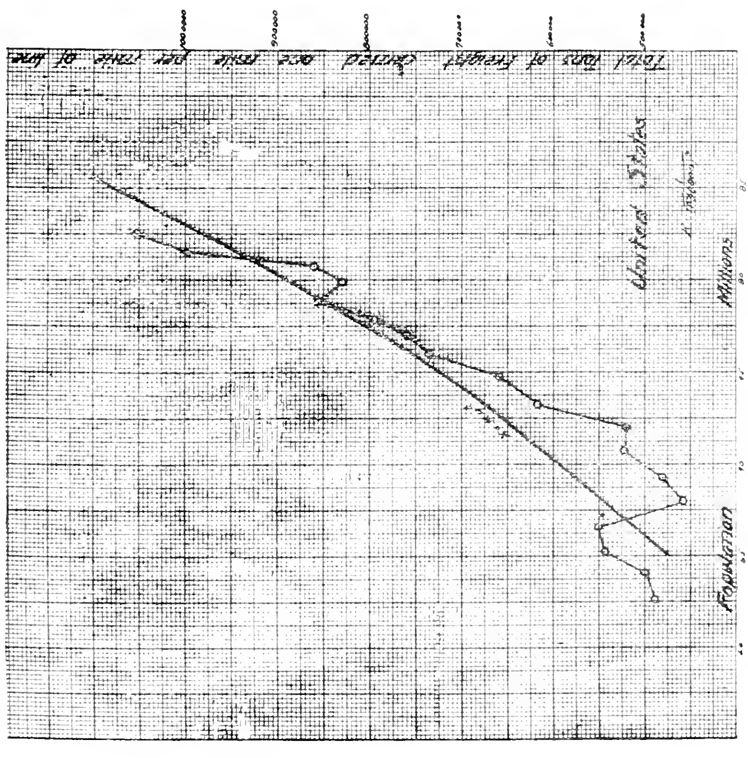


Plate 1

either axis is determined by K. The value of K must be determined for each particular problem. Then $\triangle$ represents the rate of increase of a definite quantity which is dependent upon K.

To determine the value of $\triangle$ the author has plotted upon logarithmic paper the tonnage as ordinates and the population as abscissæ. For example, on Plate 2 were plotted the total tons of freight carried one mile by all the railroads in the United States reporting to the Interstate Commerce Commission, for each of the several years from 1890 to 1907, both inclusive, and then by eye a straight line was drawn to represent the mean of the several points. The slope of this line is $340 \div 985 = 0.347$, the value of $\triangle$ for the territory and years represented. On Plate 2 are drawn three other lines having different values of the exponent $\triangle$, to show the effect of a fractional variation in the value of this exponent.

The value of K was determined from the equation $X = K\,Y^{\triangle}$, which contains three known quantities, namely, X, Y and $\triangle$. The value of K was determined solely to facilitate plotting the equation $X = K\,Y^{\triangle}$ upon plain plotting paper. (See Plate 1.)

The author used the Interstate Commerce Commission's territorial division of the United States. The territory embraced by each of these divisions, designated as groups I, II, III, etc., is shown on Plate A. The Interstate Commerce Commission for

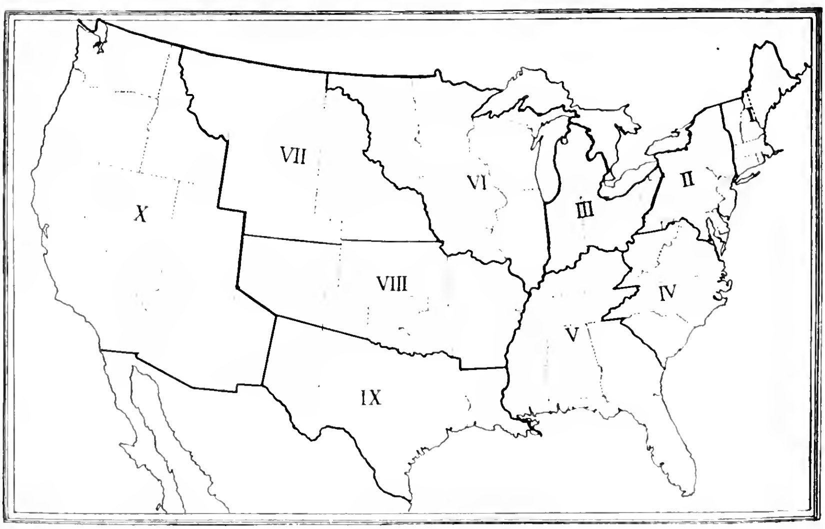


PLATE A.

certain purposes combines the above groups into so-called representative divisions as follows:

Division I comprises groups I, II and III, i. e., the territory north of the Ohio and Potomac rivers and east of Illinois and Lake Michigan.

Division II comprises groups IV and V, i. e., the territory south of the Ohio and Potomac rivers, and east of the lower Mississippi River.

Division III comprises groups VI, VII, VIII, IX and X, i. e., the territory west of Lake Michigan, Indiana and the lower Mississippi River.

$$X = K\,Y^{\Delta}$$

X = Tons Y = Population K = Constant

	Territory	Commodity		Value of Δ Approx	Value of Δ Actual
2, 1	United States	Total	carried one mile	3	$\frac{985}{340}$
4, 3	Group I	"	" " "	$\frac{5}{2}$	$\frac{982}{420}$
6, 5	" II	"	" " "	3	$\frac{982}{370}$
8, 7	" III	"	" " "	6	$\frac{100}{18}$
10, 9	" IV	"	" " "	5	$\frac{982}{210}$
12, 11	" V	"	" " "	4	$\frac{100}{23}$
14, 13	" VI	"	" " "	4	$\frac{740}{765}$
16, 15	" VII	"	" " "	8	$\frac{984}{118}$
18, 17	" VIII	"	" " "	3	$\frac{982}{290}$
20, 19	" IX	"	" " "	2	$\frac{982}{430}$
22, 21	" X	"	" " "	3	$\frac{982}{288}$
23	United States	"	originating on line	5	$\frac{500}{104}$
35, 32	Division I	"	" " "	6	$\frac{250}{41}$
35, 33	" II	"	" " "	6	$\frac{50}{9}$
35, 34	" III	"	" " "	5	$\frac{500}{106}$
31, 24	United States	Animal Products	" " "	2	$\frac{500}{245}$
27, 25	" "	Agricultural "	" " "	2	$\frac{340}{765}$
27, 29	" "	Mine "	" " "	5	$\frac{370}{72}$
27, 26	" "	Forest	" " "	4	$\frac{500}{115}$
31, 28	" "	Manufactured "	" " "	7	$\frac{50}{7}$
31, 30	" "	Merchandise	" " "	5	5

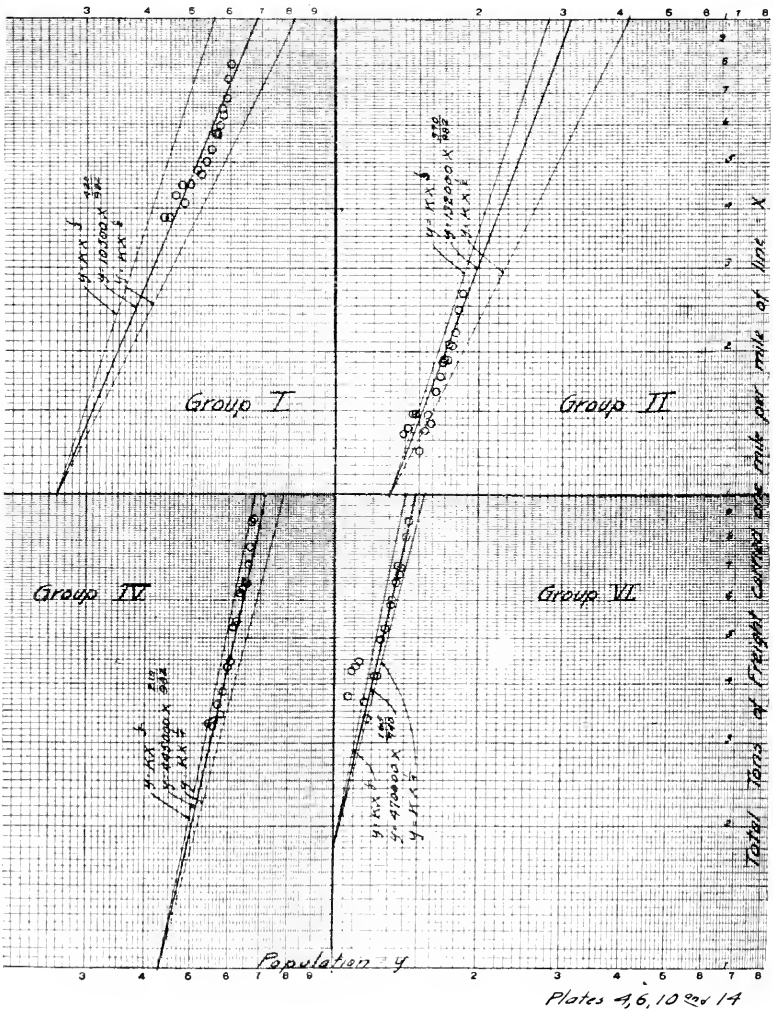
apr. 1910 G K

Plate B

[At the left are the numbers of the corresponding plates. — Ed.]

The writer found a value of $\triangle$ for (1) the total tonnage carried one mile per mile of line, (2) the total tonnage originating on the line per mile of line, and also the total tonnage of each of the following classes of products, animal, agricultural, mine, forest, manufactures and merchandise. The total amount of the products in the second item above represents about ninety-five per cent. of all the tonnage originating on the line.

The specific commodities included in each of the above-mentioned classes are as follows (classification of Interstate Commerce Commission):



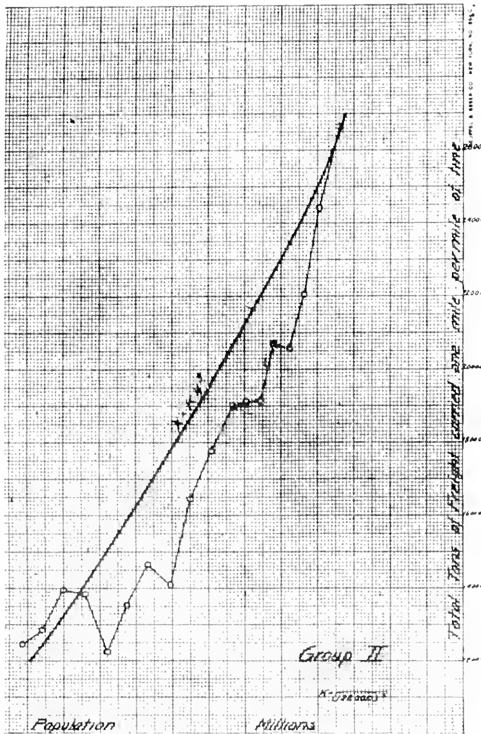


Plate 5

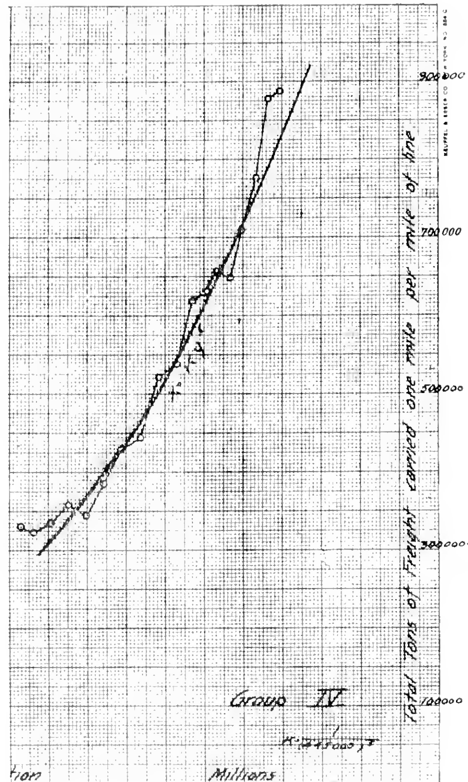


Plate 9

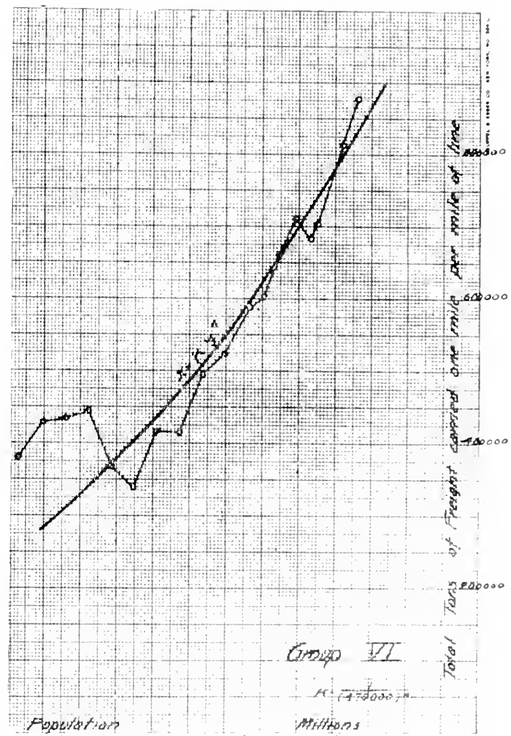


Plate 13

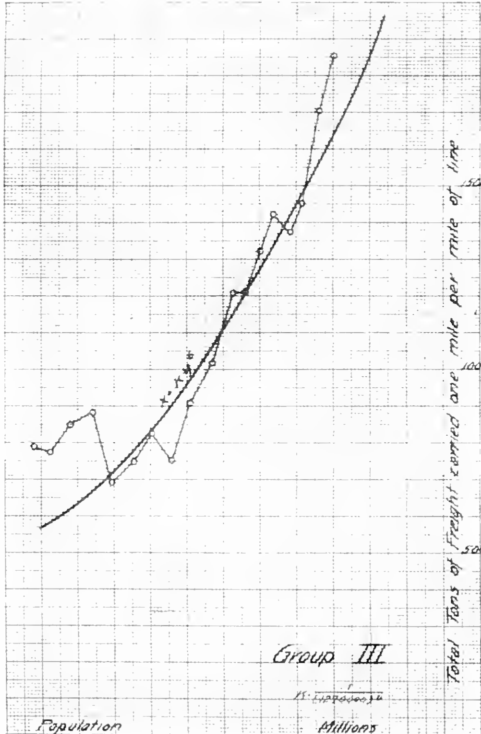


Plate 7

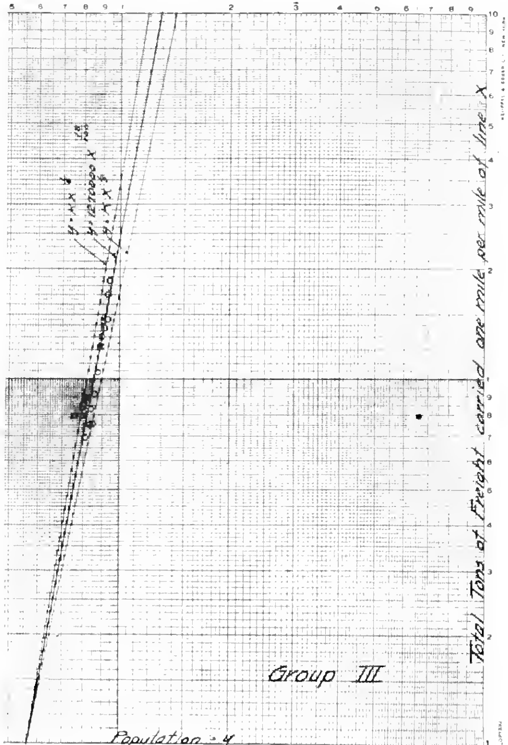
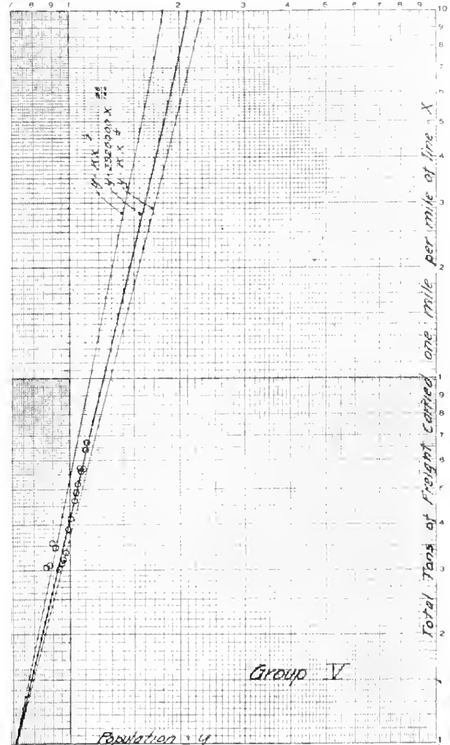
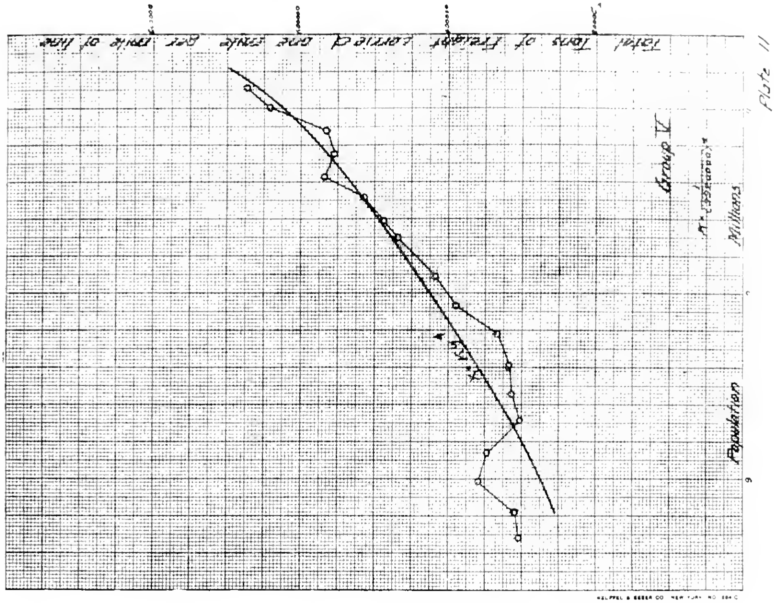
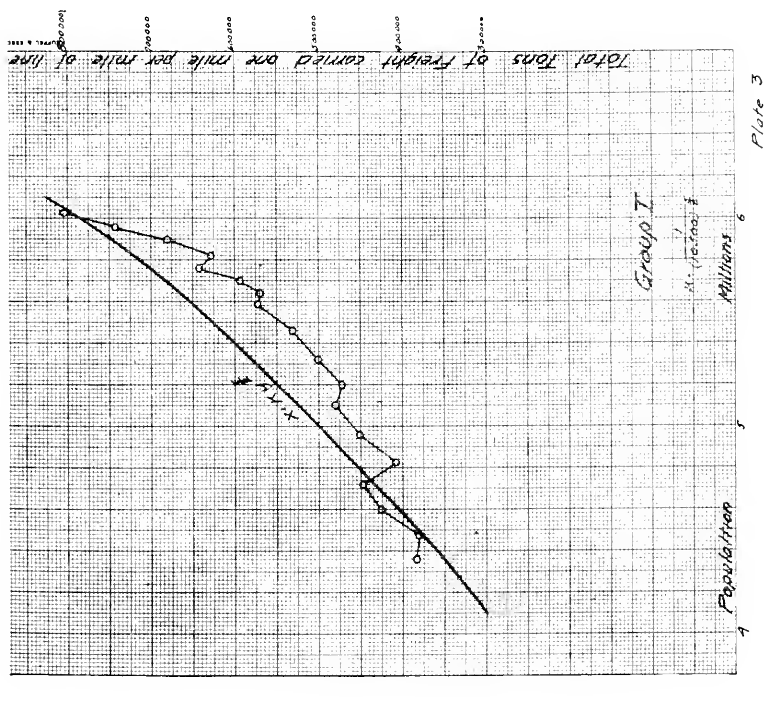


Plate 8.



Plot 12


Total Tons of Freight carried one mile per mile of line
Group V
Population
Millions
Plate 11


Total Tons of Freight carried one mile per mile of line
Group I
Population
Millions
Plate 3

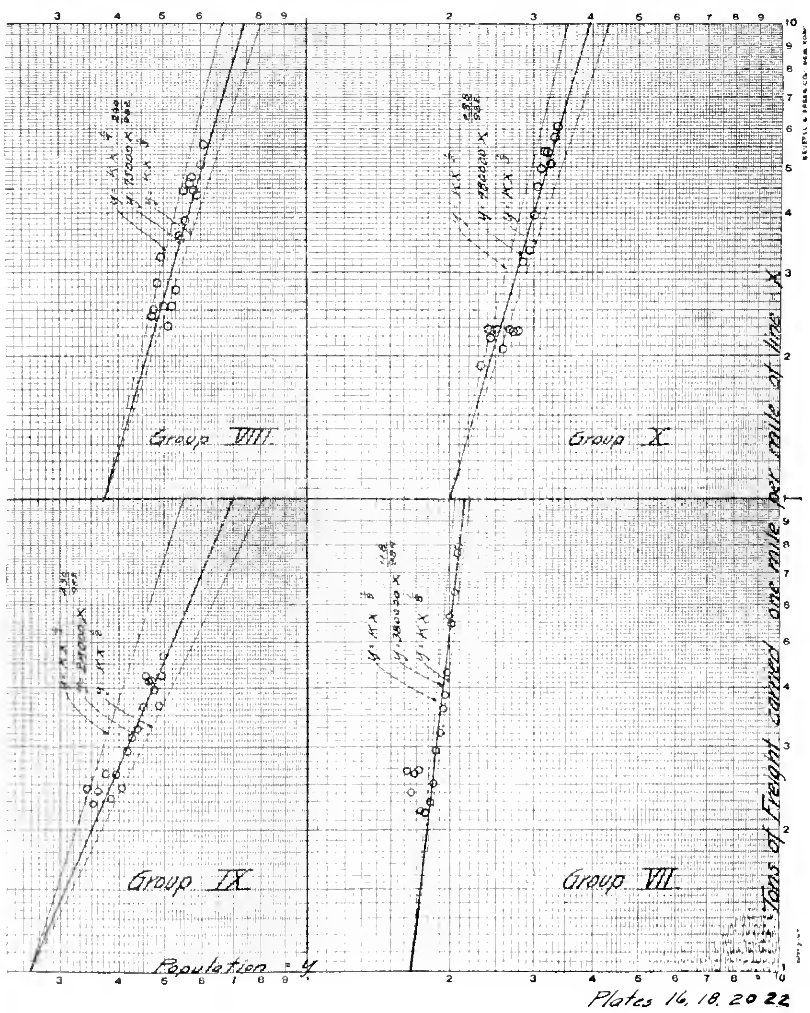
1. Products of agriculture: Grain, flour, other mill products, hay, tobacco, cotton, fruit, vegetables, etc.

2. Products of animals: Live stock, dressed meats, other packing-house products, poultry, game and fish, wool, hides, leather, etc.

3. Products of mines: Anthracite coal, bituminous coal, coke, ores, stone, sand, etc.

4. Products of forests: Lumber, etc.

5. Manufactures: Petroleum, oils, sugar, naval stores, iron (pig and bloom), iron and steel rails, castings, machinery,



Group VII.

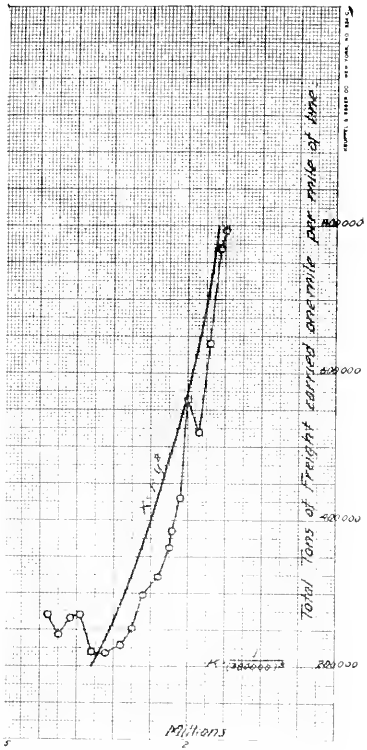


Plate 15

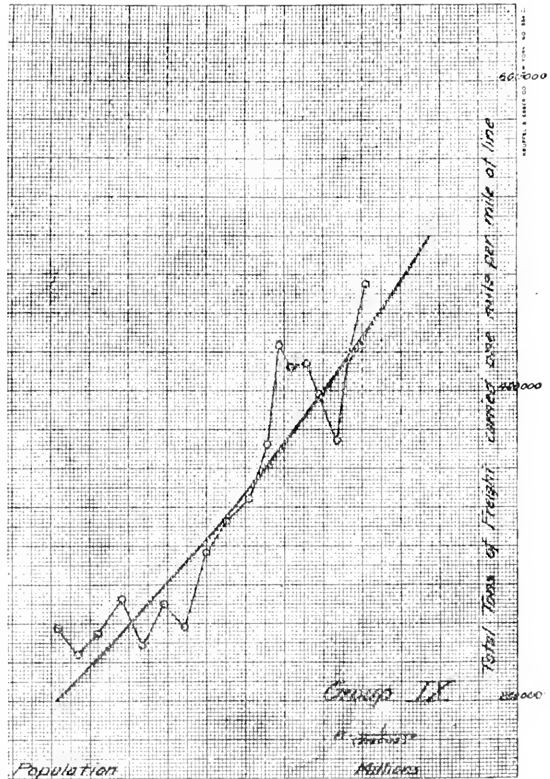


Plate 19

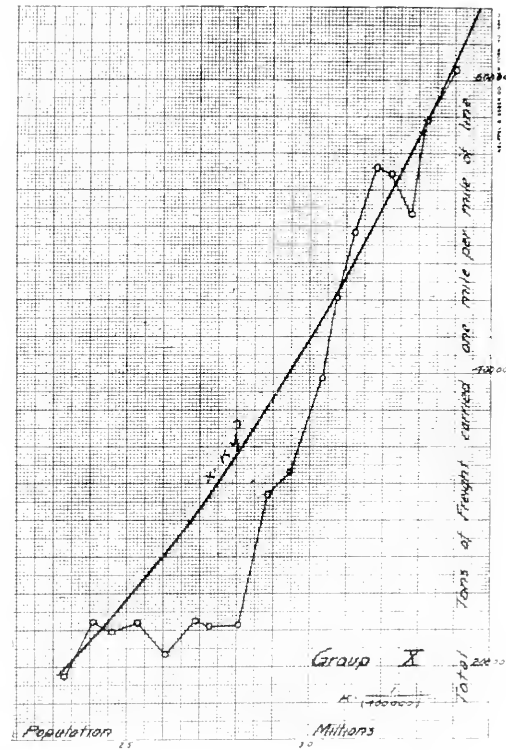


Plate 21

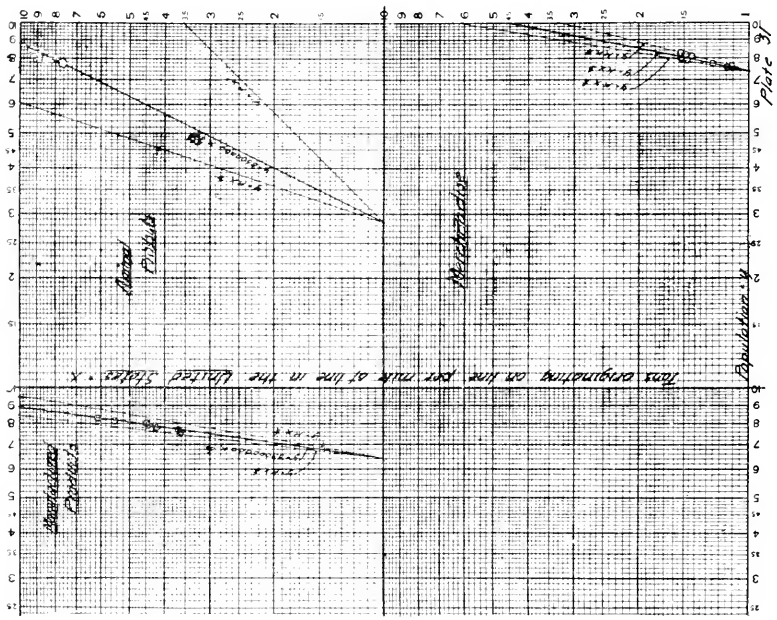


Plate 31
Tons originating on line per mile of line in the United States = x
Population = y
Merchandise
Animal Products
Manufactures Products

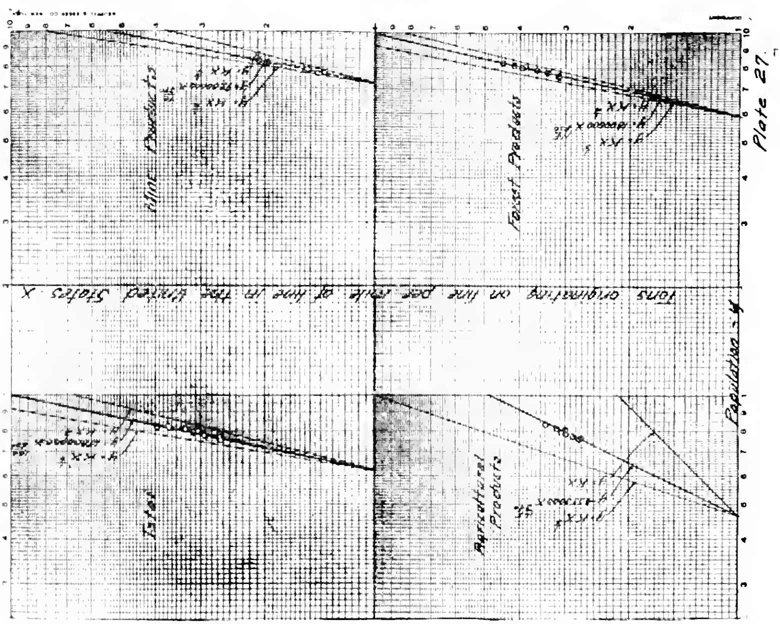


Plate 27.
Tons originating on line per mile of line in the United States x
Population = y
Mine Products
Forest Products
Total
Agricultural Products

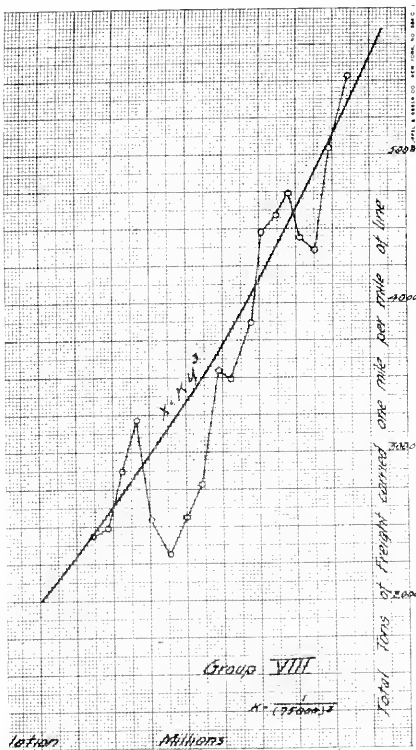
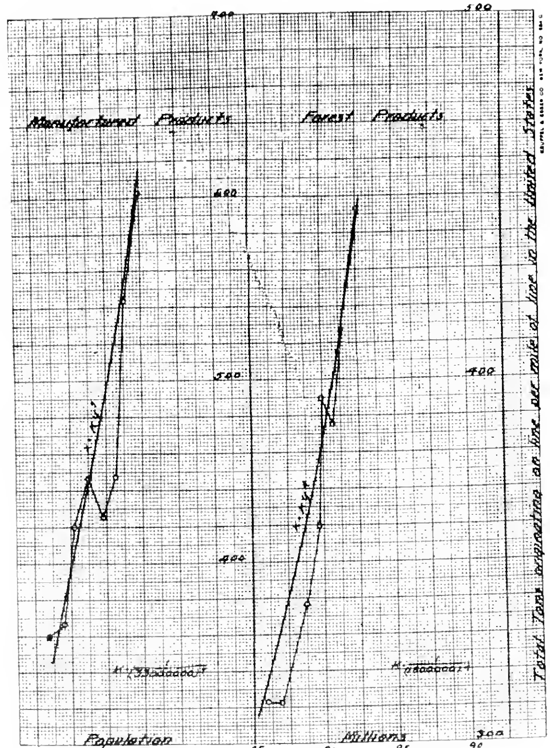
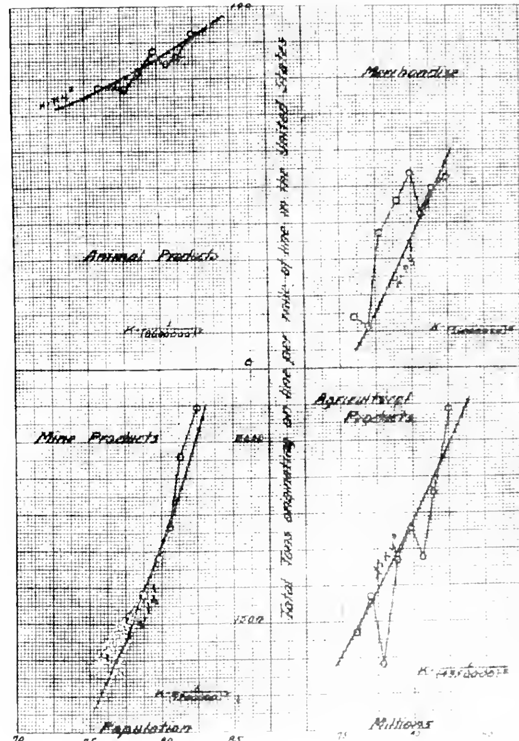


Plate 17.



Plates 26 & 28



Plates 24, 25 23

bar and sheet metal, cement, brick, lime, wagons, carriages, tools, wines, liquors, beers, household goods and furniture, etc.

On Plate B are tabulated the values of $\triangle$ for the several classes of traffic as determined from the data plotted on Plates 1-35.

To apply the preceding data in the solution of a particular case it is necessary to determine which of the several groups on Plate B most nearly represent the particular territory whose future traffic is to be estimated; we must select the group which determines the value of $\triangle$ in the equation used above. Second, the present population of the given territory must be determined.

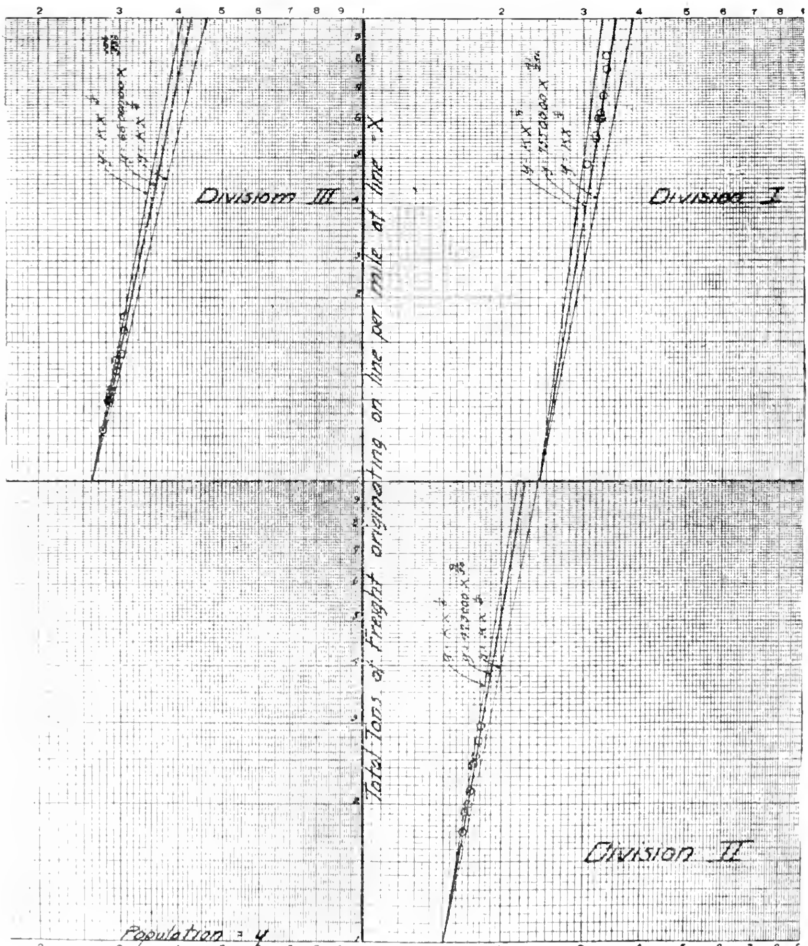
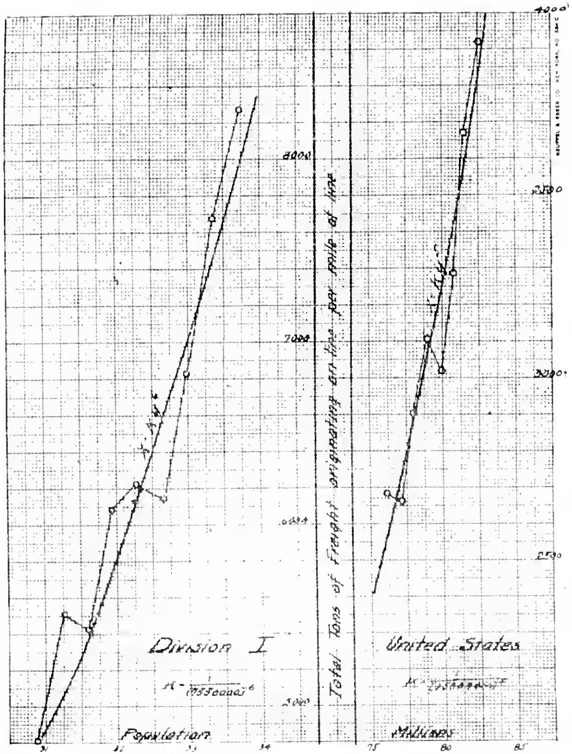


Plate 35



Plates 23 and 32

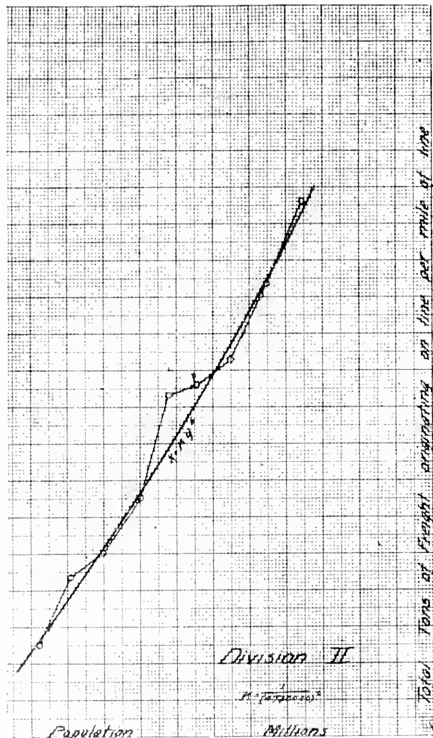


Plate 33

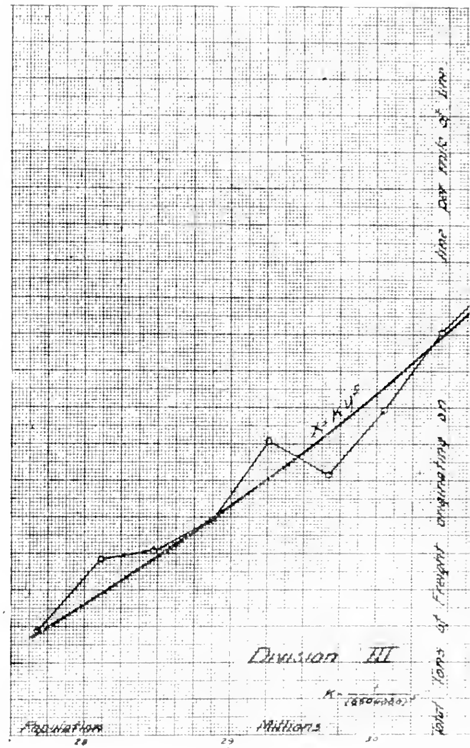


Plate 34

Third, the present traffic in that territory must also be found. This gives three of the four quantities in the equation $X = K\,Y^{\triangle}$, and by solving this equation the value of K can be found; since the value of K does not materially change for a series of years when traffic is *normal*, it may be assumed to be practically constant; and, therefore, if we can determine the probable future population, we can easily determine a value for the probable volume of traffic.

To illustrate the above, let us assume the road under consideration operates in a territory whose social and commercial conditions are similar to those of Group V; that there were 22 000 000 tons of freight carried during the past year (1910) and it is desired to determine the probable tonnage in 1920. Let us assume that the population of the territory from which the line under consideration received its business will be increased 20 per cent. during the next ten years, 1910 to 1920. The line operates in a territory similar to Group V, Plate B; and, therefore, we will use the equation $X = K\,Y^4$. Let Y equal the population in 1910, which we will represent by 1; since the increase is 20 per cent., Y equals the population in 1920 and can be represented by 1.20. Using the data for 1910 and substituting in the equation $X = K\,Y^4$, we can derive a value of K.

$$22\,000\,000 = K\,\overline{1}^4 \text{ and, therefore,}$$
$$K = 22\,000\,000.$$

The probable volume of traffic in 1920 will then be represented by X in the formula

$$\begin{aligned} X &= 22\,000\,000\ \overline{1.2}^4 \\ &= 22\,000\,000 \times 2.07 \\ &= 45\,500\,000 \text{ tons.} \end{aligned}$$

Considering what has been said above and referring to the graphs, it will be noticed, (1) that in a large majority of cases the points representing a maximum, the average of all the points, and the points representing a minimum, lie practically on curves whose exponents are the same, for each of the three cases above mentioned, K being the only variable (however, the data do not cover a sufficient interval of time to permit the drawing of any general conclusions); (2) that there is a relation between tonnage and population and that this relation can be represented by the equation $X = K\,Y^{\triangle}$; (3) that for years of normal traffic, and for years in which the percentage of deviation from the normal is the same, the value of K may be considered a constant.

The data plotted on Plates 1–22 represent the statistics for

the years 1890–1907, inclusive; on Plates 23–31 are shown the data for the years 1900–1907, inclusive; and on Plates 31–35 those for 1899–1907, inclusive.

The effect upon the above graphs of the increase in railway mileage is being considered. The statistics given are preliminary, as they will form part of a paper on the "measured increment" in railway valuation.

The writer is endeavoring to secure statistics from foreign countries where the social and commercial conditions differ from those already considered.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 15, 1911, for publication in a subsequent number of the JOURNAL.]

THE COMPRESSIVE MEMBER.

By Horace E. Horton, Member Civil Engineers' Society of St. Paul.

[To be read before the Society April 10, 1911.]

It has been asserted failures in wrought-metal structures are always in the compressive members. The failure of the Quebec Bridge is the most notable example, the main compressive members having failed by wrinkling of component elements. It could be claimed, at the time of this failure (three years ago), the design filled all the written conditions of our specifications for compressive members, said specifications having undoubtedly magnified the importance of the radius of gyration as an index to the value of the member, while neglecting entirely the question as to a member being homogeneous or built up of several sections.

The compressive member yields by bending and must have an enlarged cross section for efficiency, with material so distributed to resist inclination to deflect.

The radius of gyration has been accepted as representing relation of the proper disposition and value of material, a large radius of gyration always indicating a greater unit value for material, while a larger radius of gyration is always obtained by the use of thinner material; to illustrate (using rounds and pipe for convenience):

Member.	Section Sq. In.	Radius of Gyration.	8 Ft. 4 In. =	100 "Radii" =
4 in. solid round.....	12.5	1.	100 radii	8 ft. 4 in. long
8 in. pipe $\frac{1}{2}$ in. thick	12.5	2.5	40 radii	20.66 ft. long
16 in. pipe $\frac{1}{4}$ in. thick	12.5	5.5	18 radii	45. 8 ft. long
32 in. pipe $\frac{1}{8}$ in. thick	12.5	11.3	8.8 radii	94. 1 ft. long
64 in. pipe $\frac{1}{16}$ in. thick	12.5	24.0	4.1 radii	200 ft. long

From this example it is very apparent we must introduce a governor, or else, if left to the judgment of each designer, the radius of gyration as an index to the value of compressive members is uncertain. There must be limitations as to thickness expressed by the perimeter of the section in relation to area or direct statement of thickness of material. Specifications limit

the thickness of plate to $\frac{1}{30}$ the width, that is, 105 "radii" (length divided by radius of gyration) across the plate.

Radius of gyration may be considered through the axis of the plate transverse to length of said plate. It is apparent that in building up a member with the radius of gyration as a qualifying index, it is not reasonable to expect that "radii" may be more in primary elements than in the main member, if we are to have efficient construction. The main compressive members at Quebec were 40 "radii." The "radii" of the lattice panel of each channel was 50. The "radii" through the center of a 54-in. by $\frac{7}{8}$-in. plate, transverse to the member, is 215.

The Quebec Bridge failure emphasizes the necessity of indicating definite relation of the radius of gyration not only of the entire member, but each and every part, both transverse and longitudinal, to the end that there may be harmony; that the "radii" of a lattice panel, also the "radii" through center of plate across the member, shall be no greater than the "radii" of the entire member; or the "radii" used to determine the value of the member shall be the largest "radii" found by any of the methods indicated above of any of the constituent or individual parts.

The compressive member, with ever-increasing tendency in the evolution of design, has developed with one or more open sides on which lattice bars are used. Standard specifications have indicated a proportion for such lattice for medium and average-sized members. (One specification in terms tells us how large lattice should be and the size of rivets used therein for "largest members"; that is, $2\frac{1}{2}$-in. by $3\frac{1}{2}$-in. by $\frac{3}{8}$-in. angle with $\frac{7}{8}$-in. rivets.) This is given to show limit of demand as expressed in standard specifications, to care for "shear."

The lattice angles used at Quebec were 18 per cent. heavier than the above specifications in terms name for "largest members," and yet a comparison with actual examples of usual practice indicate that the lattice as used at Quebec were only one-fifteenth the size proportions from practice seem to demand.

The use of lattice to secure one or more of the sides of a compressive member brings prominently to our attention the necessity of recognizing an active force "shear" in a compressive member. This force surely does bear direct relation to the compression on the member. Specifications were absolutely silent on this until the Quebec failure, since which time elaborate formulas are being shown where "E" represents modulus of elasticity and "e" eccentricity. As "e," eccentricity, is arbi-

trarily arrrived at, we shall be no worse off if we arbitrarily assume a percentage of compression and call it "shear."

The main compressive members of the Quebec Bridge were built up of four channels, each built of six elements, all combined by tie plates and lattice bars riveted together.

Tests on members in compression have been more numerous in comparatively small examples of homogeneous material. Such tests indicate a decreasing value per "radii" from a cube of material to indefinite extension; while such tests as we have had on full-sized built-up composite members indicate a value never greater than 75 per cent. of the same material in tension, and from 50 to 150 "radii," decreasing in quite the same ratio but always with a reduced value as compared with the homogeneous material. This should give us pause. We must accept the compressive member built up of component, individual, constituent parts, and in no sense homogeneous.

The built channels of the Quebec Bridge were 54 in. wide, built up of four plates aggregating $3\frac{1}{2}$ in. in thickness with two angles of moderate proportions; the attachment being by rivets of usual proportions for members of one-fortieth such size.

It is elementary and well established that four plates, one laid on the other, are one fourth as strong flat ways, under a transverse load, as though the four plates were in one homogeneous whole. The $3\frac{1}{2}$ in. aggregate thickness of the webs of the built channels in the Quebec Bridge were much less value than though they had been one solid $3\frac{1}{2}$ in. thick, modified in some slight degree by the rivets passing through them, and had but a trifling influence in changing the conditions. This assertion is made incident to experimental investigation of exactly this question as to the advantage of riveting four thin plates together as compared with one of the thickness of the four, and it justifies the statement as above.

It is hoped there will be no more piling of four relatively thin plates together with a few rivets and assuming that they are homogeneous.

The omission and loss of all sense of proportion in the design of the members of the Quebec Bridge may be best understood from a comparison with standard practice.

A typical example of standard practice, two 15-in., 33-lb. channels compared with the main compressive members of the Quebec Bridge:

1. Section.
2. Proportional size.

3. Column length.

4. " Radii."

a. Radius of gyration parallel with web to radius of gyration perpendicular to web at center.

b. " Radii " length of the individual channel between lattice attachments.

c. Percentage of material in projecting flanges to area of channels.

d. Percentage of weight of lattice to weight of channels.

e. " Radii " through center of single individual element of web transverse to member.

Member.	1.	2.	3.	4.	*a.*	*b.*	*c.*	*d.*	*e.*
$\frac{2}{15}$ in. channels......	9.8	1	18.4	40	$5\frac{1}{2}$	25	33	30	113
$\frac{4}{54}$ in. Que. chan.....	792	40	56	40	13	50	4	2	215
$\frac{2}{15}$ in. channels.........					$2\frac{1}{3}$	2	15	8	2
$\frac{4}{54}$ in. Quebec channels..					1	1	1	1	1

(*a*) If the 54-in. built channel of the Quebec Bridge were homogeneous, its radius of gyration parallel with web to radius of gyration perpendicular to web at center would bear the relation of 1, while the 15-in., 33-lb. channel would be $2\frac{1}{3}$.

(*b*) The " radii " for 18 ft. 4 in., 15-in. channel is 40. The " radii " lattice panel is $62\frac{1}{2}$ per cent. of the " radii " of the member, while in the Quebec 54-in. built channel the " radii " lattice panel length is $1\frac{1}{4}$ times " radii " length of the member,—relation 2 to 1.

(*c*) In 15-in. channels the projecting flange is 33 per cent. of the entire area, while in the 54-in. built channel members of Quebec it was 4 per cent., — one eighth.

(*d*) The diagonal lattice used for two 15-in., 33-lb. channels would be 30 per cent. of the weight of the channels. The per cent. of the diagonal lattice used on the four 54-in. built channels at Quebec was 2 per cent., — one fifteenth.

(*e*) " Radii " through center of web of 15-in. channel transverse section is 113, while the " radii " transverse section of a plate 54 by $\frac{7}{8}$ in., as used in Quebec design, is 215, — 2 to 1 in favor of the 15-in. channel.

It will be noticed that all five elements of comparison, varying by ratio of 1 to 2 to 1 to 15, show lesser basis of efficiency in the Quebec design than in the standard 15-in. channel column.

It is reasonable to hope each relation, *a*, *b*, *c*, *d*, *e*, will have for the future a definite place in specifications.

Sixty years ago, in the studies leading up to the building of the Britannia Bridge in Great Britain (spans 460 ft.), with want of knowledge and after sundry and divers experiments, the rectangular tubular form was determined upon as preferable. A model of quarter size was built and tested to destruction. If in the design of the Quebec Bridge the same method of investigation had been considered, the main compressive members, $4\frac{1}{2}$ ft. by $5\frac{1}{2}$ ft. in outline, would be $13\frac{1}{2}$ in. by $16\frac{1}{2}$ in. for $\frac{1}{4}$ size. The relative channel would be composed of three plates $13\frac{1}{2}$ in. by 7/32 in., one plate $9\frac{1}{2}$ in. by 7/32 in., and two angles 2 in. by $1\frac{1}{2}$ in. by 7/32 in. — $\frac{1}{4}$-in. rivets (sizes not exact to 1/128 in.), four such channels, with lattice of 1 in. by $\frac{3}{4}$ in. by 3/32 in. connected with 7/32-in. rivets; this member to act and be the main support for a 450-ft. span. It is apparent, if any such investigation had been started, it would never have gone further than the mere outlining of the member as above, because it would be obvious there was something wrong in the design from the proportions.

Following out practice to form the main member for a 450-ft. span with four $13\frac{1}{2}$-in. built channels as $\frac{1}{4}$-size model of an 1 800-ft. span, $\frac{1}{16}$ the cross section for relative member in 1 800-ft. span; this approach to the subject would give us a section entirely within our grasp and comprehension. We would use for each of the four channels a $13\frac{1}{2}$ in. by $\frac{1}{2}$ in. plate and two angles $2\frac{3}{4}$ by $2\frac{3}{4}$ by $\frac{1}{2}$ in.; a double lattice on account of four channels, $2\frac{1}{2}$ by 7/16 in.—rivets $\frac{3}{4}$ in. The above dimensions are quite on the lines of a well-proportioned comprehensive member as we know. Multiply each dimension by four for a member of sixteen times the area and we have web plates 54 in. by 2 in. — two angles 11 in. by 11 in. by 2 in. Four such channels in the member, double latticed with 10-in. by $1\frac{3}{4}$-in. bars all combined with 3-in. rivets, and practice by direct proportion shows us the member to use in the 1 800-ft. span.

The proportions as here indicated for the lower chord members of the Quebec Bridge present a difficulty. To have maintained the same clearance between backs of channels and edge of interior angles would have forced the building of the member 26 in. wider than designed, and here undoubtedly we have the immediate cause for using angles with such small projecting flanges. The detail, pins, tie plates, lattice, not only of the lower chords, but through the entire structure, would have been in-

creased at least $33\frac{1}{3}$ per cent., which would have amounted to thousands of tons in the entire structure.

It may be argued that some other method would better serve the purpose. This may be true. My purpose is trying to indicate what practice extended by common sense would have required in a 54-in., 4-channel, lattice compressive member for the lower chords of the Quebec Bridge.

Slight investigation will show that cover plates $\frac{3}{4}$ in. thick would weigh no more than the lattice as indicated above and could be more conveniently and efficiently connected to the flanges; in fact, the connection could be thoroughly efficient and definite. For purpose of makeup in construction it might and probably would be necessary to cut manholes through such cover plates.

Again, if lattice be used by using a multiple series, — say four sets, — one each on the outside and again on lines of one third the depth of the channels, that is, 18 in., it would be possible to introduce and connect the lattice and build the member of material no more than one inch thick. The difficulty in all this is the amount of labor involved in this internal longitudinal stiffener system.

Physical conditions are stubborn, but physical conditions have to be met. To design and carry to successful issue an 1 800-ft. span bridge has never been accomplished.

The largest span frame structure built, the Forth bridge, span 1 730 ft., has its main compressive members of 12-ft. circular tubes. Comment has been made on this fact in comparison with the rectangular compressive members used at Quebec. Atmosphere and the treasury have much to do with modifying design. The Forth bridge had $9\frac{1}{2}$ dead load to 1 of live. The Quebec design had $4\frac{1}{3}$ dead load to 1 of live; this merely indicating that higher unit stresses were contemplated at Quebec than were used at the Forth, as there was nothing in the general proportions of the structure to represent the different relations of live and dead load.

The engineers of America have failed with the rectangular compressive member. That the failure is incident to the form of the member is not proved; in fact, the engineers of America know only too well the form of the member had nothing to do with the failure.

The design of component parts of any structure is a matter of give and take; if compressive members of proportions required in the Quebec Bridge were made of round figures, the

difficulties of connections would have been increased by a very large ratio. The engineers of America believe and know this ratio to be out of all proportion to the lesser value of the rectangular figure as compared with the circular one, but accept the failure for exactly what it is, the most staggering engineering disaster of the age. While they regret the disaster, they accept the fact with every confidence that their practice will successfully evolve even greater spans than the one attempted at Quebec with absolute certainty of result whenever the opportunity affords.

With the Quebec Bridge down, it is very natural to make comments and criticisms as above. It is one of the problems for students in lines of advanced thought to solve why it takes a great catastrophe to fix attention and correct error in any of the many subjects of human endeavor.

Thirty years ago, in Great Britain, 13 spans, 200 ft. each, approximately 100 ft. from the water, were blown away with a train of cars full of people into the Firth of Tay. An investigation showed that the towers (cast-iron columns), some 80 ft. or more high, were so inefficient in collapsing by pressure of wind, that of twelve such towers only three disturbed the masonry. Sir Benjamin Baker's testimony, from investigation, gave it as his conclusion, that the wind force that caused this disaster did not exceed 15 lb. per square foot of exposed area. He also testified that this particular structure was no better or worse than essentially all the high structures on metal towers built in Great Britain. Further investigation of the foundations of the Tay Bridge indicated that if the towers had been stable for the pressure of, say 25 lb. of wind, on the bridge and train, that the masonry piers supporting the metal towers would have been overturned by such a force. It is needless to say that, due to this disaster, there was an investigation as to the stability of structures in Great Britain. Since then rules have established 56 lb. per square foot as the force computed acting over the entire surface of any structure built. It has not come to my notice that any structure has blown down in Great Britain since the Tay Bridge. We regret the sacrifice of the whole trainload (every single individual on the train being drowned), but it was not entirely in vain. It corrected a wonderfully unfortunate tendency in tower design in Great Britain.

The death of the seventy-five at Quebec has some compensation. It will correct grave error.

The individuals sustaining the financial loss can also know that it has not been entirely in vain.

To the engineers concerned, the engineering profession extends its heartfelt sympathy, each and every one admitting backsight is better than our foresight. We all admit doing those things we should not have done, and omitting the things we should have done. Our friends' loss is the profession's gain.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 15, 1911, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF PAPER, "STERILIZATION OF PUBLIC WATER SUPPLIES."

(VOLUME XLVI, PAGE 12, JANUARY, 1911.)

MR. LANGDON PEARSE. — Mr. Johnson has called attention to the character of the portion of the Chicago River locally known as Bubbly Creek. He particularly emphasizes the condition of the east arm, on which the Stock Yards Filtration Plant is located. The only liquid admitted to this arm, to the writer's knowledge, is the sewage from the local sewers and the main 20-ft. conduit from the Thirty-Ninth Street Sewage Pumping Station, and such lake water as may be flowed through by gravity or by pumping for flushing out that arm of the river. Otherwise the arm of the river would be a dead end. The flow figures are very much greater than Mr. Johnson states. The average quantity of sewage pumped between October 18, 1909, and November, 1910, was 78 million gallons daily, or about 289 gallons per capita. The maximum daily flow was 293 million gallons and the minimum 43 million gallons. This is the total flow, no estimate being made for ground water, as it seems probable that leakage at present is small. The flow of lake water through the conduit in addition to the sewage may be as much as 500 cu. ft. per second. If we take the average daily flow of 78 million gallons, the gravity flow makes a dilution of about one part of sewage to four of lake water. When both flushing pumps are running at the Thirty-Ninth Street Pumping Station, the total flow of lake water may be as high as 2 000 cu. ft. per second. This will give a dilution of about one of sewage to 17 of lake water. It is important to note that when the pumps are running, the gravity flow stops, as automatic check gates close, preventing the inflow of lake water through the conduit. The character of the sewage is dilute, as compared with that of typical American cities. Mr. Johnson's comments still hold, however, that the purification of such a foul water as that of Bubbly Creek is an epoch in the annals of water purification. The difficulties of operation are naturally increased by the changes in dilution.

It may be of interest to note that four to six parts per million of available chlorine are required to sterilize the dry-weather

flow of normal sewage at Thirty-Ninth Street. No experiments have been made on the sterilization of the mixture with lake water. In connection with Mr. Phelps' paper, it is pertinent to state that about one part per million of available chlorine has been found sufficient to sterilize the non-putrescible effluent of experimental sprinkling filters at the Thirty-Ninth Street Testing Station.

OBITUARY.

William Henry Bryan.

Member of Engineers' Club of St. Louis.

William Henry Bryan was born August 14, 1859, at Washington, Mo. He died at Chicago, December 6, 1910. He was a descendant of Daniel Boone the pioneer, and the son of the late Capt. Archibald S. Bryan, well known as an owner and master for many years of river steamers operating on the Missouri, Mississippi, Osage, Gasconade and Yellowstone rivers. The son spent much time on the river, absorbing here his first knowledge of mechanics, filling every position on a steamboat from "roustabout" to master. During this time he attended the Washington, Mo., schools, preparing himself for a college course. He also studied railroading and telegraphy, becoming an expert operator in the service of the Missouri Pacific Railroad. He entered the Academy of Washington University, St. Louis, February, 1876, entering the freshman class of the School of Engineering the next fall, and taking the course in mechanical engineering under the late Prof. Charles A. Smith. He was graduated from Washington University in 1881, with the degree of M.E.

Mr. Bryan spent his summers previous to graduation in the service of the Missouri Pacific Railroad in its telegraph offices and shops. After graduation he entered the service of Frank H. Pond as assistant in the design and erection of steam plants, and selling of steam and machinery specialties, where he remained eight years, during which time the Pond Engineering Company was formed, Mr. Bryan becoming secretary. In 1889 he was appointed secretary and local manager of the Heisler Electric Light Company, then pushing its system of long-distance series incandescent lighting. From the latter Mr. Bryan went to Chicago as manager of the western branch of the Yale & Towne Manufacturing Company in 1891.

In 1892 he opened an office in St. Louis as consulting engineer in mechanical, electrical and hydraulic work of an expert and professional character, in which he was engaged until the time of his death. He was a pioneer in this kind of work in St. Louis. During the period from 1896 to 1900, this work was

carried on as a partnership with Henry H. Humphrey, under the firm name of Bryan & Humphrey. Mr. Bryan was tendered several public positions of trust in St. Louis, among them being supervisor of city lighting, assistant water commissioner and chief engineer of the board of education, but remained in independent professional practice until shortly before his death, when he accepted an attractive and responsible position as chief engineer of the Board of Education of the city of Chicago. He was appointed to this position on competitive civil service examination in which he received the highest grade.

Mr. Bryan was a close student of steam boiler performance, furnaces, smoke abatement, heating and ventilation, and the mechanical equipment of modern commercial buildings. He made a great many evaporative boiler trials, in which work he was considered an authority, and was prominent in many local movements, such as smoke abatement, in which connection he served the city of St. Louis as smoke commissioner under the original ordinance and as chairman of the Civic Improvement League committee on smoke abatement.

Allied lines have also commanded his attention, such as water works, lighting and power plants. His work covered a wide range of territory from Wisconsin to Texas and from New York to California. The most important work was the design of the plant of the Imperial Electric Light, Heat and Power Company, of St. Louis, a 2 000 kw. electric power plant with compound condensing engines, economizers and induced draft, storage battery auxiliary and underground distribution. The mechanical equipment of a large department store in Los Angeles, Cal., was perhaps his most important isolated plant.

In addition to his regular work as an engineer, he made it a practice to compile valuable and interesting engineering data, and at the time of his death had in preparation an engineer's notebook on heating and ventilation. He designed the heating and ventilating plants of the new City Hall and the Young Men's Christian Association building, St. Louis.

He was a frequent contributor to the engineering press and proceedings of the engineering societies. Among papers presented to the American Society of Mechanical Engineers are, "The Down-Draft Furnace for Steam Boilers," "Western River Steamers," "The Mechanical Equipment of Modern Commercial Buildings," "The Relations between the Purchaser, the Contractor and the Engineer," and "Some Considerations Regarding Direct-Connected Generators."

To the Engineers' Club of St. Louis he contributed papers on "Long and Short Stroke Engines," "The Efficiency of Steam Engines," "Steam Boiler Performance," "Smoke Abatement in St. Louis," "The Efficiencies of Heating Systems," "The Engineer of To-day," "A History of the Engineers' Club of St. Louis," read at its thirtieth anniversary. To the American Society of Heating and Ventilating Engineers he presented an exhaustive paper on "Central Station Heating." He was a regular contributor to the columns of the *Age of Steel*, the series containing articles on "Chimneys," "Western River Steamers," "Street Railways of St. Louis," "The Engineer in the City," and others. Articles on the smoke problem to *Cassier's Magazine*, and on the street railways of St. Louis to the *Engineering Magazine*. A fully illustrated review of "The Louisiana Purchase Exposition from the Standpoint of the Engineer" was prepared for the *Engineering Magazine*. Articles on the Mississippi River Steamer to the *American Engineer* in 1881. An address before the Washington University Association on "The Mechanical Engineer," since published in *The Engineer*. Article on the new St. Louis ferry steamer *Christy* in *Marine Engineering*, and talks on same before the Engineers' Club of St. Louis and the St. Louis Railway Club.

Mr. Bryan was called to various cities as an authority on smoke abatement, and delivered many addresses on this subject, among them being two before the faculty and students of Purdue University and the University of Illinois.

The death of Mr. Bryan will be a great loss to a number of societies. The organizations that have felt his influence the most are the Alumni Association to which he belonged and in which he served four terms as president, the Washington University Association and the St. Louis Engineers' Club.

The following is taken from the resolutions adopted by the Washington University Association and refers to him:

"He entered the association as one of its charter members, retaining his membership and keeping up his vigorous interest until the time of his death. From 1901 to 1905, and again from 1907 to 1908, he served on the council; he filled the office of treasurer from 1901–5, and in 1910 he was elected president of the association. Mr. Bryan manifested an almost unique devotion throughout his long and unbroken connection with our organization. He interpreted his untiring expenditure of labor in the interest of the association as a duty imposed by the deep affection he bore his alma mater. To the performance of this noble duty he bore to the end of his days the undiminished en-

thusiasm of youth blended with the ripened sagacity of long experience, buoyed and steadied by an extraordinary vigor in the execution of work."

He joined the Engineers' Club of St. Louis in 1884 and was active in its affairs. He was secretary from 1887–91, and 1894–97, vice-president 1897, and president 1898. He was always an enthusiastic worker in the affairs of the Engineers' Club, having its success and influence constantly before his mind. He was vice-chairman of its special committee in charge of the entertainment of visiting engineers to the World's Fair, in which work he was very active. Was chairman of the subcommittee in charge of the preparation of Division 3 of the club's World's Fair souvenir, devoted to a compilation of local engineering data.

Member American Society of Mechanical Engineers, the American Society of Heating and Ventilating Engineers, the Engineers' Club, and was ex-treasurer of the Washington University Association, and president at time of his death. Also member of the Mercantile Club and the St. Louis Railway Club.

Mr. Bryan was married in 1885 to Miss Mary Ruge, of Washington, Mo., and had a family of two boys and three girls. Mr. Bryan was an incessant worker, always finding something to do in all spare moments. He was a constant reader, having a wide acquaintance with the literature of his profession. As an engineer he was careful in forming opinions, but when an opinion was fully formed he was not easily swerved from it. He had high ideals of the duties and responsibilities of the consulting engineer, and was always ready to sacrifice personal profit and prestige in carrying out those ideals. His disposition was characterized by a marked devotion to his family and loyalty to friends.

> "His life was gentle; and the elements
> So mixed in him, that Nature might stand up
> And say to all the world, 'This was a man.'"

H. H. Humphrey.
Edw. Flad.
S. Bent Russell.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVI. APRIL, 1911. NO. 4.

ECONOMIC GENERATION IN THE MODERN CENTRAL POWER STATION.

ERRATUM

In Mr. George A. Johnson's paper on "Sterilization of Public Water Supplies," in the January, 1911, JOURNAL OF THE ASSOCIATION, page 14, 24th and 26th lines,

FOR 8 million gallons READ 8 million cubic feet.

equipment and transmission, with interest and maintenance to be earned on each. Each company must have sufficient generating equipment to carry it over the peak load, as well as a large reserve for emergencies. In places where the service can be adequately furnished by one company alone, such duplication with its accompanying low economy of generation and distribution is now regarded as a waste of capital. Such waste must sooner or later increase the cost of electricity to the consumer.

The demand of the public for low rates has led to the appointment of public service commissions in various states and countries, whose duty it has been to investigate the causes for high rates and to advise means for equitable regulation. The reports of many of these commissions show that in the electric light business where there are two or more companies in com-

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVI. APRIL, 1911. NO. 4.

ECONOMIC GENERATION IN THE MODERN CENTRAL POWER STATION.

BY E. H. TENNEY, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, February 1, 1911.]

THE tendency of modern power companies toward combination and centralization has not been brought about through a desire to stifle competition and control prices, but rather through the realization on the part of the public and competing companies that economy in the production of electric power is increased not by competition, but by cöoperation and concentration.

The reasons are obvious. Where there are competing companies there will be a duplication of capital invested in buildings, equipment and transmission, with interest and maintenance to be earned on each. Each company must have sufficient generating equipment to carry it over the peak load, as well as a large reserve for emergencies. In places where the service can be adequately furnished by one company alone, such duplication with its accompanying low economy of generation and distribution is now regarded as a waste of capital. Such waste must sooner or later increase the cost of electricity to the consumer.

The demand of the public for low rates has led to the appointment of public service commissions in various states and countries, whose duty it has been to investigate the causes for high rates and to advise means for equitable regulation. The reports of many of these commissions show that in the electric light business where there are two or more companies in com-

petition in the same field, rates will be higher than would be the case where one company, under proper municipal control, produces and distributes all the power.

The lowest price at which any commodity can be sold will depend primarily upon what it costs to produce that commodity and put it upon the market. Hence we see the modern lighting company, in the endeavor to meet the public's demand for low rates, first merging with its competing neighbors, then proceeding systematically to develop to the utmost limit all of the many economies possible in the central power station.

Grades of Coal.

The sole object of a power plant is to transform the energy lying dormant in the fuel into dynamic electric energy and deliver it as such at the switchboard. The greatest field for economy lies in the different steps of this transformation.

The first step in the process, and probably the most important, from an economic standpoint, takes place in the boiler plant. Here the heat energy of the coal must be transferred to the water in the boilers. The portion of the available heat of the coal that will be absorbed in the boiler will depend upon several considerations, one of which is the coal itself.

Whether to use a high-grade, high-priced coal, or a cheaper coal; whether to use lump, mine run, screenings or a mixture, are questions which are almost wholly to be determined by boiler and furnace equipment. For any given installation the grade of coal best suited to the grate upon which it is to be burned, will — as a rule — be most economical regardless of price.

Chain grates with sufficiently small air spaces and links so designed as to allow of minimum droppage are well fitted to burn low grades of nut, pea and slack coal.

On other chains where the space between the links allows a large excess of air, the same grade of coal with a higher percentage of slack could be used with no decrease in the intensity of the fire, although the higher percentage of droppage might make it poor economy.

The rate of evaporation of a boiler is a good test of the coal being burned on the grate. Coals of like quality and grade produce nearly identical rates of evaporation on a given grate. For this reason, in stations where there are many facilities for conducting evaporative tests, a very definite knowledge is possi-

ble of the rates of evaporation that may be expected with each kind of coal which comes into the station. The method of buying coal on a heat unit basis has been tried and is having good success among some central stations. Here, aside from stated premiums and penalities in connection with the calorific value of the coal, other penalties are attached for excessive amounts of ash and sulphur. In burning high-grade coals with the intensely hot fires which they make possible, the frequency of tube replacements and the length of life of the setting are points which have to be taken into consideration. As a rule, low grades of coal of low calorific value and with a high percentage of ash are well suited to automatic chain grates where good drafts are available. On hand-fired grates, where it is necessary to extend the interval between boiler clean-outs as far as possible, it is extremely poor economy, if not altogether impossible, to make use of very low grades of coal.

One point of importance in the handling of low grades of coal is the high percentage of sulphur that they often contain. When sulphur burns, sulphur dioxide gas is formed. This gas, uniting with oxygen supplied from the moisture in the coal and air, forms sulphur trioxide, which deposits as a white crystalline powder on the surfaces of the tubes, breeching and stacks. This substance being the active element in sulphuric acid needs only the addition of moisture to make it a source of serious deterioration. Moisture is present in all stack gases, and readily condenses on the inner surfaces near the top. Some of this moisture collected and analyzed had the strength of twentieth normal sulphuric acid. The stack from which this sample was taken had to be renewed after being in service two years. In the case of a few boilers, where extremely hot fires were maintained, this sulphur trioxide was found in combination with iron oxide on the lower row of tubes as yellow sulphate of iron. This, however, was not accompanied by any noticeable deterioration of the metal.

Economy in Boiler Operation.

There are many points in the firing of a boiler that have such a marked effect on combustion and on the resulting boiler efficiency that they cannot be overlooked, although to one who has not seen their comparative effects on efficiency, they may seem of minor importance. The question as to the proper amount of surface moisture in the coal that will give the best results in

the fire is one often argued. The results of many tests show that hottest fires are obtained where there is from seven to nine per cent. of surface moisture. Especially poor grades of slack, that can only with difficulty be kept burning when fired dry, will liven up and make a fairly good fire when moistened. Aside from the question of heat lost and gained through dissociation of the moisture thus supplied, — which is very probably nearly an even balance, — the reason for this improvement in the fires may be accounted for by the fact that the moisture on vaporizing and expanding in volume throughout the body of the fire opens up small passages through which necessary air may be carried to the fuel. This is borne out by the fact that the combustion of a coarse grade of coal is not assisted by surface moisture nearly to the extent that is the case with slack coal. Repeatedly it has been demonstrated that the higher the percentage of slack, the greater is the amount of surface moisture needed for successful combustion.

Thickness of fuel and speed of the grate are other points the importance of which is often lost sight of. On automatic grates a fire that is too thin will burn " short " at the back of the grate, admitting a great volume of excess air. This cools the gases, interferes with proper combustion and decreases the boiler efficiency. A fire that is too thick will roll up at the bridge wall, causing a sluggish fire and restrict the passage of air up through the grates. Here the combustion is imperfect with a loss of efficiency as before. On the hand-fired grates the results of careless firing are the same. Coal improperly spread will be thick and smoldering in one place and burned through in others, both conditions indicating loss of efficiency. In general, lump, nut and pea, and mine-run coals will burn best with thick fires, while slack, or pea and slack, will give best results when fired thin.

Operating boilers in batteries so as to get the best draft is another point in boiler-room economy. In a stack designed to care for several boilers, the maximum efficiency will be had only when all the boilers are fired together. The working out of this is shown by two tests conducted on the same boiler under exactly similar conditions, the only difference being that in one test all four boilers of the battery were forced up to capacity, while on the other only the boiler being tested was under fire, the dampers from the other boilers being closed. The results of these tests showed that with only one boiler on the stack there was a loss of 25.2 per cent. in the intensity of the draft, a loss of 18.9 per

cent. in capacity and a loss of 2.59 per cent. in efficiency. Such losses as these should be carefully taken into account when it is necessary to bank boilers in the station during a large part of the day. Best economy calls for running and banking in batteries.

FEED-WATER ECONOMY.

After liberation from the coal, the heat energy is taken up by the water in the boilers to be passed on as steam to the generators. The amount of heat energy that can be taken up by the boiler and used in evaporating water will depend largely upon the water. A good boiler feed-water should be clear and free from scale-forming matter; it should not contain acid or alkalies of such strength as to cause pitting or corrosion; nor should it have an excess of any substance which by concentration will cause priming or foaming.

In St. Louis our water supply must almost of necessity be from the Mississippi River. This water in its untreated condition has many qualities which are undesirable in a boiler feed-water. It sometimes contains as high as 35 grains per gallon of scale-forming substances. It is very turbid, the suspended matter often amounting to 350 grains per gallon. It is of comparatively high alkalinity, and during certain seasons of the year, especially the late summer months, when the suspended solids are composed largely of organic matter, there is a scum-forming element in the water which tends to cause foaming.

To prescribe any definite and fixed formula for a treatment of this water that would make it suitable for use in boilers would be impossible on account of the constantly varying quantities of the impurities. Hence a general scheme of treatment must be used, which can be adjusted at any time and at short notice to meet each change of condition of the river water.

The system for purifying and softening Mississippi River water for boiler use now in successful operation at the Ashley Street Station of the Union Electric Light and Power Company is based on the Wixford process of clarification and is similar in all essential principles to the system in use at the St. Louis City Water Works. Briefly, it operates in the following manner.

The raw water is first run through a calibrated nozzle and brought into intimate contact with proper charges of milk of lime, sulphate of iron and soda ash. The mixture is then delivered to a series of settling basins, in which the coagulation and sedimentation take place. The clarification is completed by the aid of two beds of fine excelsior, through which the water

must pass before it is delivered clear, neutral and soft to the hot wells.

To explain the method of adjusting the amount of chemicals to be added to the raw water necessitates mention of the changes which occur in the raw water itself, and of the conditions which bring about these changes. These effect three qualities of the water, namely, its alkalinity, turbidity and color.

The alkalinity, by which is indicated the amounts of the carbonates of lime and magnesia as they exist in the raw water, varies with the seasons and the stage of the river. The amount of mineral matter dissolved by the water as it passes over the beds of the creeks and rivers will depend on the amount of the carbon dioxide which the water contains. During the warm months, decaying vegetation is constantly supplying large amounts of carbon dioxide, which is the product of animal and vegetable life. This in turn, dissolved by the rains, unites chemically with the carbonates of the minerals as they lie along the beds of the rivers, forming the soluble bicarbonates. Thus the actual amount of mineral matter supplied to the river varies with the seasons. Also, the actual number of grains per gallon of these substances will vary with the amount of water which is flowing. With the river at the 20 ft. stage, the solutions will be less concentrated than at the 10 ft. stage, and the alkalinity of the water will be lower.

The reactions taking place between these soluble bicarbonates and the milk of lime with which the water is treated is represented by reactions 1 and 2 thus:

(1) $CaH_2(CO_3)_2+Ca(OH)_2=2CaCO_3+2H_2O$.

(2) $MgH_2(CO_3)_2+2Ca(OH)_2=Mg(OH)_2+2CaCO_3+2H_2O$.

A certain amount of free carbon dioxide is also in the water which reacts with the lime — as in reaction No. 3:

(3) $Ca(OH)_2+CO_2=CaCO_3+H_2O$;

thus it is readily seen that the smaller the amount of bicarbonates in the raw water, the less will be the amount of lime necessary to add for purification. This charge of lime usually varies throughout the year from 4 to 10 grains per gallon.

The resulting normal carbonate of lime ($CaCO_3$) is only slightly soluble in water and precipitates out readily, carrying down with it to a greater or less degree the suspended matter in the water. The hydrate of magnesia, $Mg(OH_2)$, settles out slowly and must be met by the soda ash and precipitated as magnesium carbonate ($MgCO_3$) lest it get into the boilers and impart its cementing qualities to any scale that may be present.

By careful observation of the river bulletins and by frequent alkalinity tests many changes in the quality of the water may be met as soon as they occur. A quick rise in the river usually denotes a sudden drop in the alkalinity and vice versa.

The turbidity, by which is indicated the amount of suspended matter in the water, is a very variable quantity. When the water supply is taken from near the banks of the river the turbidity will be found to be very much higher than that of the water in midstream. During the winter months, too, when the ground is frozen, the turbidity of the water is much lower than at other seasons of the year. Were the turbidity low enough, say 200 parts per million, the precipitation from the reaction between the milk of lime and bicarbonates in the water would be sufficient to clarify the water without the use of sulphate of iron, in which case the iron is omitted from the treatment. However, when the suspended matter is high and a large part of it organic, as is sometimes the case, the flocculent precipitate from the ferric hydrate is necessary to a satisfactory coagulation and sedimentation.

All of the impurities in the raw water are reduced by the treatment with lime and iron except any sulphate of lime ($CaSO_4$) that may be present. This is slightly increased as shown in reaction No. 4:

(4) $FeSO_4 + CaH_2(CO_3)_2 = FeH_2(CO_3)_2 + CaSO_4$.

This sulphate of lime ($CaSO_4$) is then combined with its proper amount of soda ash and reacts as in equation No. 5:

(5) $CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$,

the sodium sulphate going through into the boiler where it remains in solution.

The bicarbonate of iron in equation (4) is acted upon by the lime as in equation (6):

(6) $FeH_2(CO_3)_2 + 2Ca(OH)_2 = Fe(OH)_2 + 2CaCO_3 + 2H_2O$,

and the ferrous hydrate — $Fe(OH)_2$ — combining with water and oxygen, becomes ferric hydrate as in equation (7):

(7) $2Fe(OH)_2 + H_2O + O = Fe_2(OH)_6$,

which forms a flocculent precipitate. The charge of sulphate of iron varies throughout the year from zero to 3.5 grains per gallon.

The color of the raw untreated water gives a fair indication of the amounts of organic matter in solution, and although the color varies somewhat widely throughout the changes of season, it is not a large factor in determining the necessary charges of chemicals. Usually the charge of iron is sufficient to carry down the excess organic matter along with the other impurities.

The amount of soda ash which it is possible to use with a boiler feed water is limited by the particular conditions under which the plant is operated. Enough soda ash should be used to react with all of the sulphates of lime and magnesia in the raw water, in addition to a small amount necessary to care for the hydrate of magnesia and the sulphate of lime which is formed by the bicarbonate of lime acting on the sulphate of iron as in reaction No. 4. This cannot be done in all cases, however, as the resulting sulphate of soda quickly concentrates in the boilers and causes priming. Each boiler plant using the water would have to determine by a careful series of tests just what amount of soda ash could safely be used. From one-half to one grain per gallon is a safe amount where the boilers are washed every ninety days. The criterion in each case, however, is the degree of concentration which occurs during the interval between boiler clean-outs. From 300 to 400 grains per gallon is a safe figure for the allowable concentration in ordinary tubular boilers. In locomotive boilers the concentration cannot be carried safely over 50 grains per gallon.

Boiler-Room Equipment.

Aside from the coal and water supply, the boiler-room equipment itself offers many opportunities for economies. Arrangement of boiler passes can sometimes be changed so as to bring the hot gases into more general contact with heating surfaces, and increase efficiency. Eddy currents in the gases as they pass around the baffles cut down the efficiency of the adjacent heating surfaces to a marked degree.

The condition of the boiler setting also has its effect on efficiency. Loose settings with numerous air leaks around headers and drums make bad economy. The air drawn in through such leaks cools and dilutes the gases, interfering with proper combustion and at the same time decreasing the intensity of the draft.

Air will leak through a brick setting to a greater or less degree. Two series of readings were recently made at different planes in the third pass of a vertical pass boiler to show the variation in the carbon dioxide content of the gases. On one series the gas samples were taken 24 in. inside the rear header, and on the other, 45 in. Lines were drawn through points having the same percentage of CO_2 as shown in the accompanying charts (Figs. 1 and 2). These contours indicate very clearly the points in the setting at which air leaks and eddies were found.

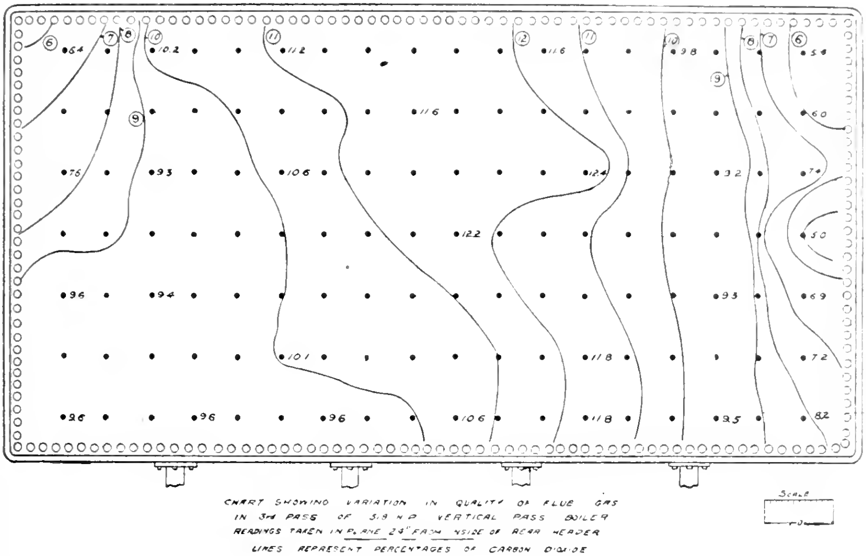


FIG. 1.

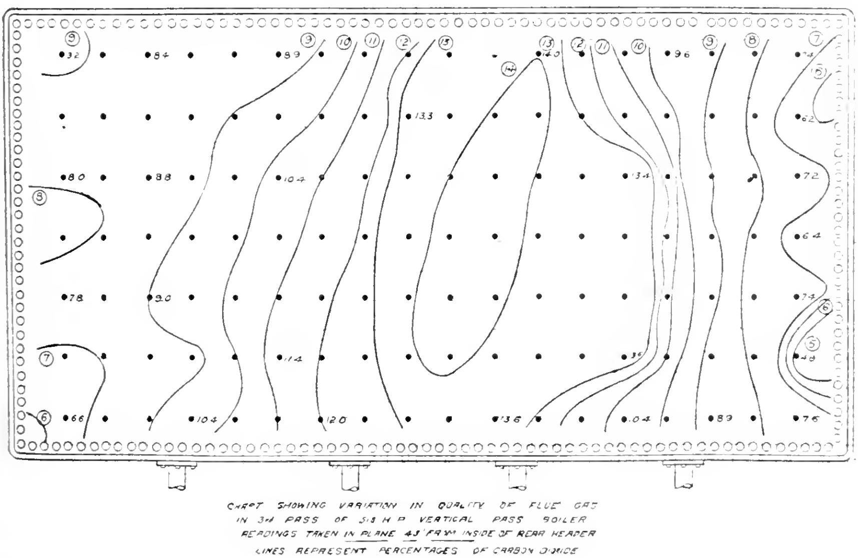


FIG. 2.

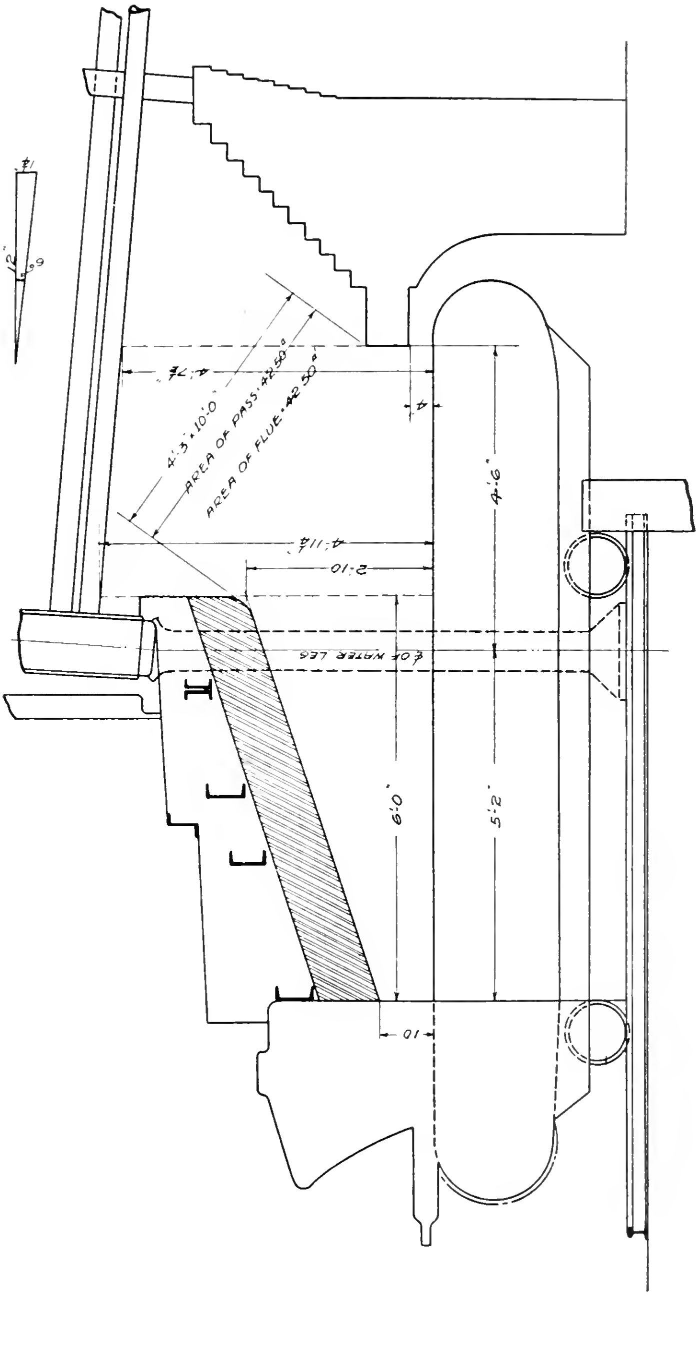
On chain-grate boilers beneath which are large ash hoppers connected to adjacent boilers, a small but decided loss in efficiency is experienced when air is permitted to get into the hop-

pers, and pass up behind the ends of the grate into the furnace. It is largely to the elimination of this loss in efficiency that the success of the "water-back" is due. A heavy forged steel water-back of square section, so placed as to overhang the flat part of the last link for about three inches at a distance four inches above the grate, will allow the ash as it reaches the end of the grate to make a joint which will entirely eliminate the admission of this excess air. The water-back also makes a substantial addition to the heating surface of the unit.

The position of feed-water inlets should be at a point near the path of water circulation and as far as possible from mud-drum or cleanout connections. To connect feed-water pipes to mud-drums or rear water legs is not in accord with most successful boiler practice. The top of the front header or drum are much more successful points at which to make feed-water connections.

Economy in Furnace Installation.

The furnace presents several interesting and important points in economy. One of the first questions that arise in a boiler plant installation is in regard to the advisability of installing automatic stokers or hand-fired grates. The size of the plant and the firing space available, as well as other questions of economy and convenience, will assist in determining this. In general, hand-firing is out of the question in large central stations. Plants operating any great number of boilers find it poor policy to avoid the outlay of capital necessary for automatic grates, at the expense of putting the operation of their boiler plants at the mercy of firemen. Aside from continued inconvenience and confusion, the high cost of maintaining large gangs of firemen, coupled with the actual losses in efficiency and capacity during cleanout periods, make the economy of hand firing in a large plant a very uncertain quantity. Where furnaces of the chain grate and Dutch oven type are operated it has been found that the position of the rear end of the arch with respect to the lower tubes has a decided effect on the life of the tubes. In settings where the tile at the rear of the arch are located close to the tubes, and where a very high draft permits of excessive and continued over-rating of the boiler, the life of the tubes is greatly shortened by overheating and bulging at the point just above the nose of the arch. This may be due to one or both of two things: First, blow-pipe action, in which case the rapidly moving flames impinge strongly against the tubes, or,



SECTION AT CENTER LINE OF BOILER

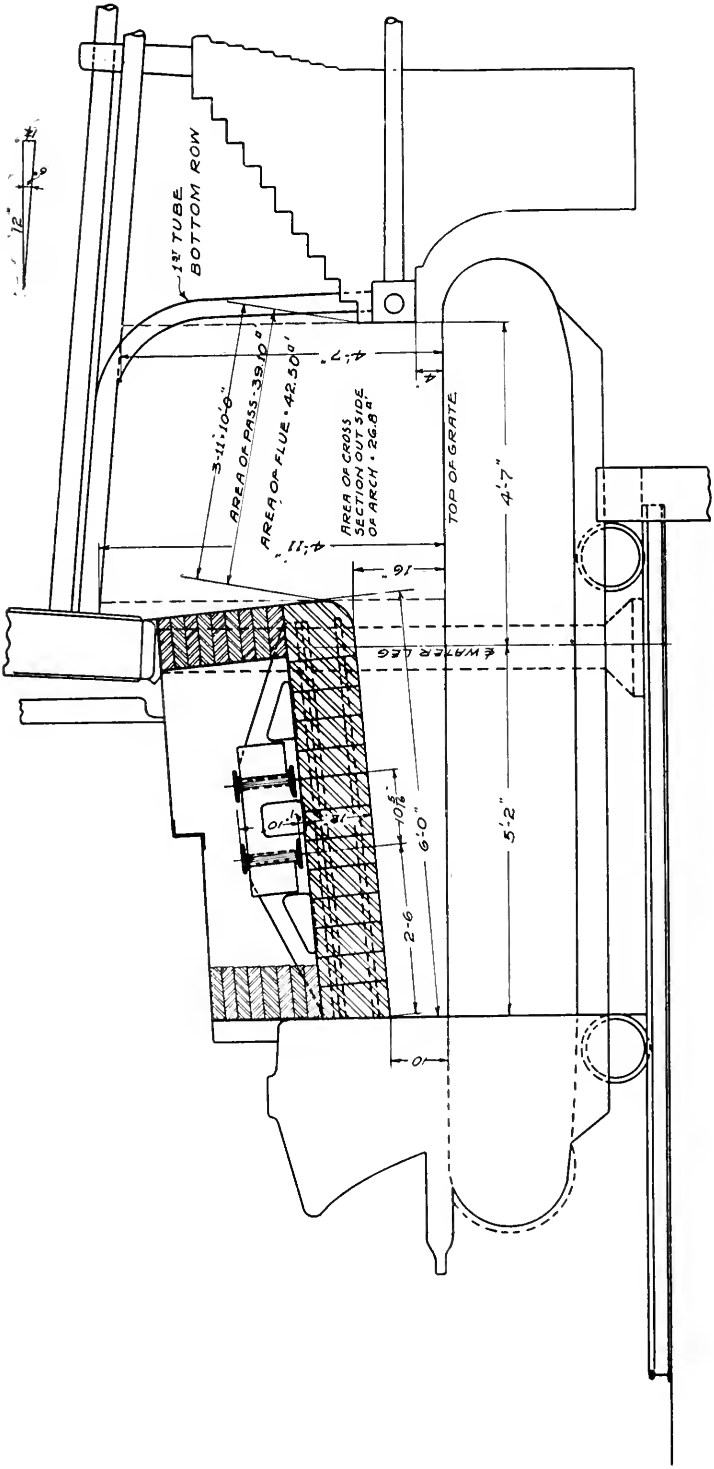
FIG. 3.

secondly, it may be due to scale. Loose pieces of scale as thin as $\frac{1}{32}$ in. will sometimes collect in the bottom row of tubes and become cemented together, forming a patch of material almost impervious to water, making the metal of the tube beneath highly subject to burning. Not infrequently has it been necessary to renew the tubes after four weeks' service. A partial remedy for this is to drop the rear of the arch well below the tubes. This gives a much greater horizontal spreading effect to the flames. Good success has also been obtained with the flat arch. Here the impinging action on the tubes is at a minimum, but a restricted area for the liberation of the gases immediately over the fire has to be avoided.

The question of boiler arches is one which has had a great deal of attention at Ashley Street. In the original Edgemoor boiler installation the arches were 6 ft. long (Fig. 3), flat and suspended from above by small so-called arch I-beams which were fastened in turn to transverse channel irons supported by the side castings of the stoker frame. These original arches were 10 in. above the grate at the front and sloped up toward the rear to 34 in. This made the area of the opening between the nose of the arch and the nose of the bridge wall 42.5 sq. ft., which is the same as the area of the flue leading from the boiler into the breeching. It was found, however, that with an arch of this design two practical considerations made a change advisable. In the first place, the gases being free from any restriction in the furnace were found to be passing the arch with high velocity and were consequently heating the arch to only a comparatively low temperature. As a result of this the ignition of the coal was slow. On some of the poorer grades of slack the coal would travel 12 in. from the gate before igniting. To retard the speed of the grate and thicken the fire was not a successful way of overcoming this difficulty with ignition. When thick fires are maintained with low-grade slack or pea and slack the air supply from below the grate is effectively shut off, and a red smoldering fire results. More than probably a thick bed of coal would not be completely burned when it reached the end of the grate and would be carried over into the ash pit or rolled up upon the bridge wall. Low-grade Illinois coals are very high in ash and sulphur, and a thick bed of ash on the rear of the grate invariably forms huge clinkers which are apt to be the cause of great annoyance. A fire six inches thick is as heavy as is practicable with ordinary Illinois nut, pea and slack, and as the percentage of slack increases, the allowable thickness of the

fire will be less. This pulling of the fuel away from the grate before ignition naturally cuts down the useful grate area of the unit as well as admits to the furnace a considerable amount of cold excess air. This in turn further reduces the temperature of the arch, cools and dilutes the gases, and shows itself definitely in a low boiler capacity and efficiency. On Illinois coals the capacities formerly obtained on these boilers when equiped with the original design of arch and with available breeching drafts of about 0.65 in. were but little in excess of the rating, while the efficiencies averaged about 60 per cent. On the higher grade coals the difficulty of heating the arch and obtaining early ignition was practically eliminated and much higher capacities and efficiencies were obtained. A second practical difficulty which made the question of a change of this arch of importance was the continued blistering and burning of the lower row of tubes. The points at which this blistering occurred were confined to that portion of the tubes directly above the nose of the arch and extending for about 18 in. back toward the bridge wall. The gases seemed to be liberated from the arch at a point too close to the tubes, permitting a strong impinging action just where the combustion was most intense.

The first change which was made was on a boiler selected for experimental work and consisted of lowering the rear of the arch from 34 in. above the grate to 16 in. (Fig. 4). This proved to be a step a little too far in the other direction. While the area of the opening between the arch and bridge wall was cut down by only 3.4 sq. ft., leaving plenty of area for the liberation of gases after they passed the arch, the volume beneath the arch was so far cut down as to restrict the liberation of the gases and retard combustion. For this reason the arch was again changed after one or two tests. This time the distance of the nose above the grate was made 27 in. (Fig. 5). This was found to be a very successful height, and is the height to which most of the arches have been changed in the Edgemoor boilers at Ashley Street. These changes, coupled with an increase in draft from 0.65 in. to 0.80 in., accomplished by the addition of 34 ft. to the height of the stacks, brought up the average efficiency on the lower grade coals to 63.4 per cent. with an average capacity raised from 7 per cent. in excess of the rating to 37 per cent. This change also gave much more satisfactory results in the ignition, and there was a marked decrease in the number of burned tubes. On the higher grade coals capacities as high as 897 h.p., and efficiencies of 68 per cent., were obtained.



SECTION AT CENTER LINE OF BOILER No 27

Fig. 4.

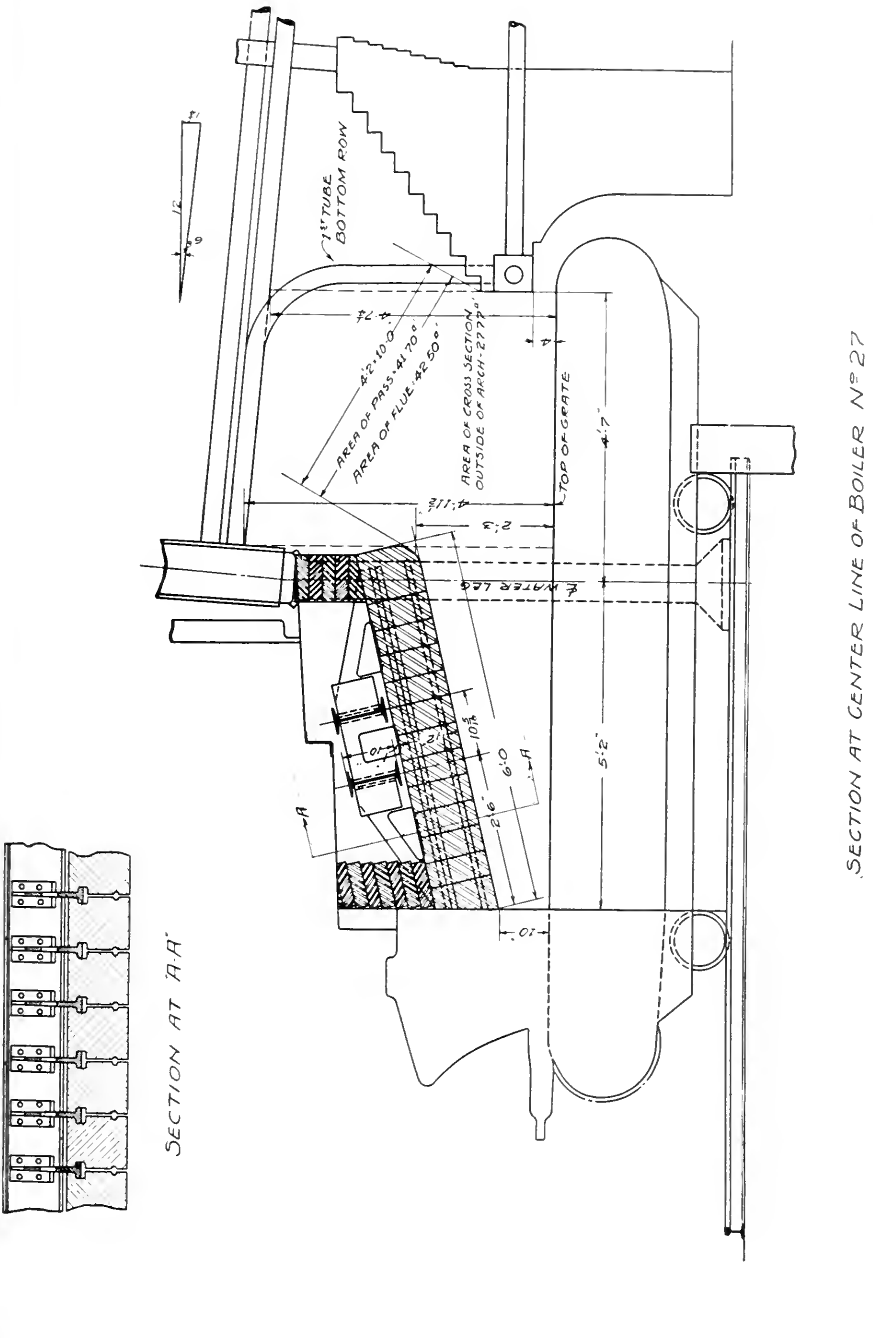
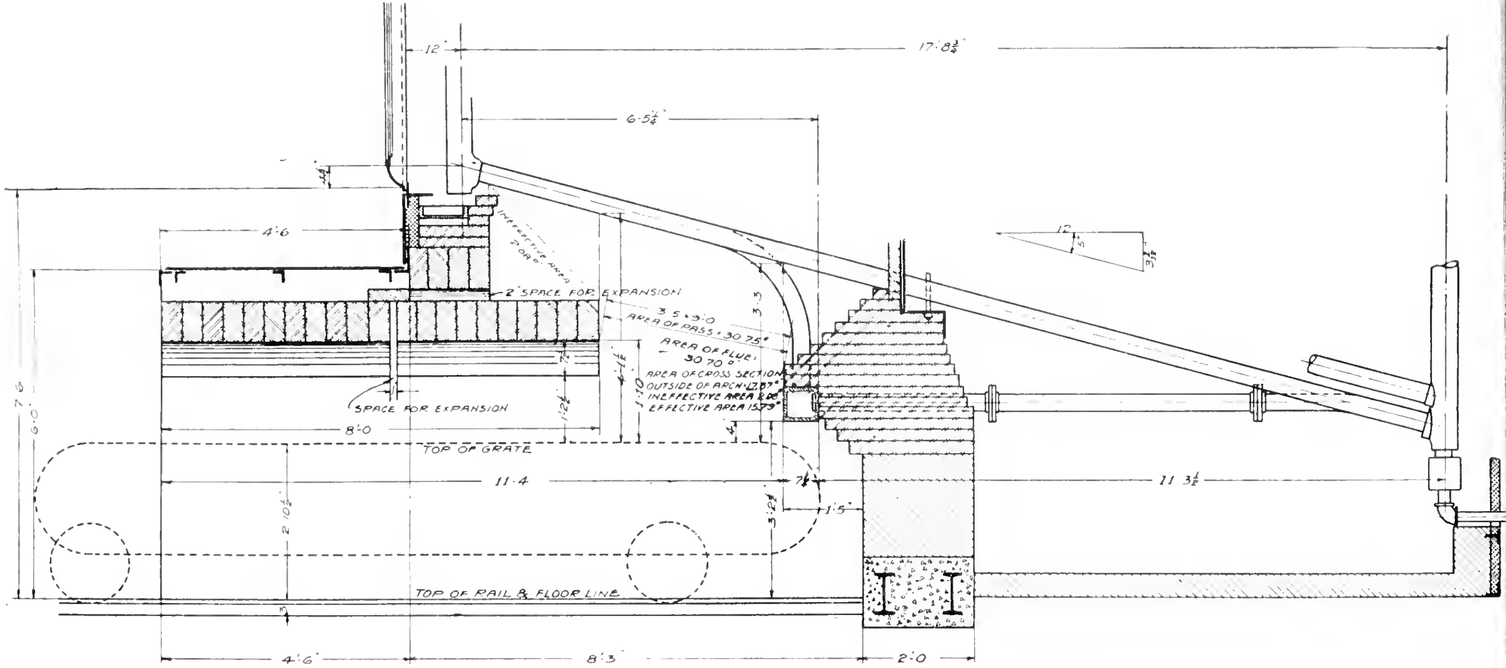
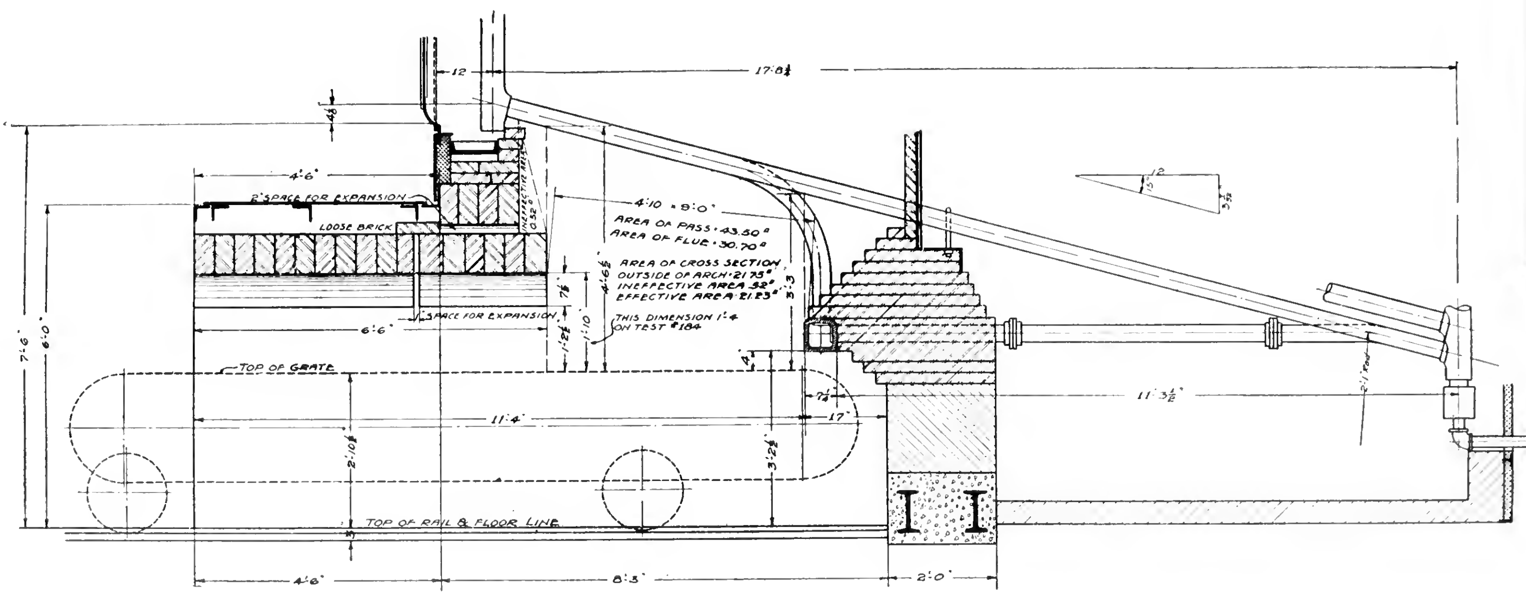

SECTION AT CENTER LINE OF BOILER No 27
SECTION AT 'A-A'
1ST TUBE BOTTOM ROW
AREA OF PASS 41.70 □'
AREA OF FLUE 42.50 □'
AREA OF CROSS SECTION OUTSIDE OF ARCH 27.72 □'
TOP OF GRATE
℄ WATER LEG
4'.7"
5'.2"
2'.3"
6'.0"
2'.6"
A
A

FIG. 5.



SECTION AT CENTER LINE OF BOILER No 1 TO 12

FIG. 6.



SECTION AT CENTER LINE OF BOILER No. 13

FIG. 7.

An addition of twelve 508 h.p. Babcock & Wilcox boilers has recently been made to the equipment at Ashley Street. These boilers have an available draft in the breeching of 1.4 in., due to new 250-ft. stacks 13 ft. in diameter. On these boilers, with low-grade coals, capacities as high as 50 per cent. in excess of rating have been obtained, with efficiencies of about 67.0 per cent. With higher grade coal a horse-power of 1 250 has been obtained, with efficiency of 69.91 per cent. Before this horse-power was obtained, however, it was necessary to make a change in the design of the arch as originally installed. The original arch was of the form shown in the sketch (Fig. 6). With this length of arch the area for liberation of the gases was restricted to such an extent that there was a retarding of the combustion. This, however, was easily relieved by shortening the arch, making its length 6 ft. 6 in. instead of 8 ft. (Fig. 7). This change increased the capacity from about 1 000 h.p., to 1 250, as stated.

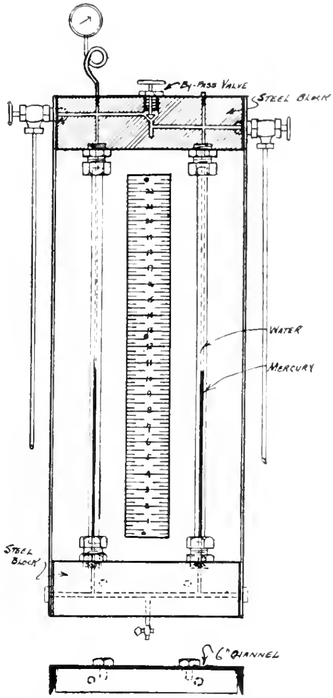
To determine the best conditions for economy in furnace design requires a great deal of thought and experimenting. Probably no two stations present the same conditions or requirements. Some stations are required to operate their furnaces with a minimum of smoke. Here the bridge wall and arches may often be so adjusted to the setting as to give very satisfactory results. In other stations more stress can be laid on points in furnace design that have a greater effect on economy.

Steam Piping.

Another important point in boiler-plant equipment is the size of steam piping. This is a consideration that enters into the original design of the plant, and is a source of more or less difference of opinion among engineers. Steam headers designed for a maximum steam velocity of 8 000 ft. per minute are considered good practice. But where these same headers have to carry steam from a highly overloaded battery of boilers at the rate of 11 000 ft. per minute the economy is doubtful. The areas through which steam is sometimes required to pass are often so restricted as to cause a serious loss in pressure and economy.

A special differential pressure gage has been designed for determining difference in pressure between any two points in high-pressure steam lines. This instrument (Fig. 8) is made of two capillary tubes about 22 in. long, connected at the bottom and top by high-pressure fittings and works on the principle of

an ordinary U-tube draft gage. The bottom half of the instrument is filled with mercury or carbon tetrachloride, according to the range in pressure to be measured, and the upper half with water. By opening the small by-pass valve at the top, pressure is admitted to both sides of the instrument at the same time. The by-pass valve is then closed, and the difference in pressure between the two points will be indicated by the unequal position of the liquid in the tubes. The difference in pressure is then figured out after applying a correction for the unequal columns of water above the fluid.



DIFFERENTIAL PRESSURE INDICATING INSTRUMENT FOR INDICATING SMALL DROPS IN HIGH PRESSURE STEAM LINES.

FIG. 8.

The accompanying curve (Fig. 9) shows the drop in pressure in a 12-in. steam lead connected to a 12 000 kw. generator at various loads. To determine these readings, the instrument was set up midway between the two points, between which the drop in pressure was to be measured, and so placed that the $\frac{3}{8}$-in. pipes could drain away from the instrument and back into the steam line. These points were 47 ft. apart, and in this distance the steam was deflected, through bends, a total of 160 degrees. With this instrument it was possible to trace and locate the most serious sources of pressure loss in the station.

A large loss was found through the superheaters on the boilers. The average loss in pressure here was 3.5 lb. per sq. in. on a 518 h.p. boiler working up to its rating. Another loss was through angle non-return valves on the steam lead just outside the boiler. Under normal working conditions there was a drop of 1.08 lb. through this valve. When the inside of this valve was removed, the loss in pressure amounted to only 0.57 lb., showing that a loss of 0.51 lb. was due to the moving

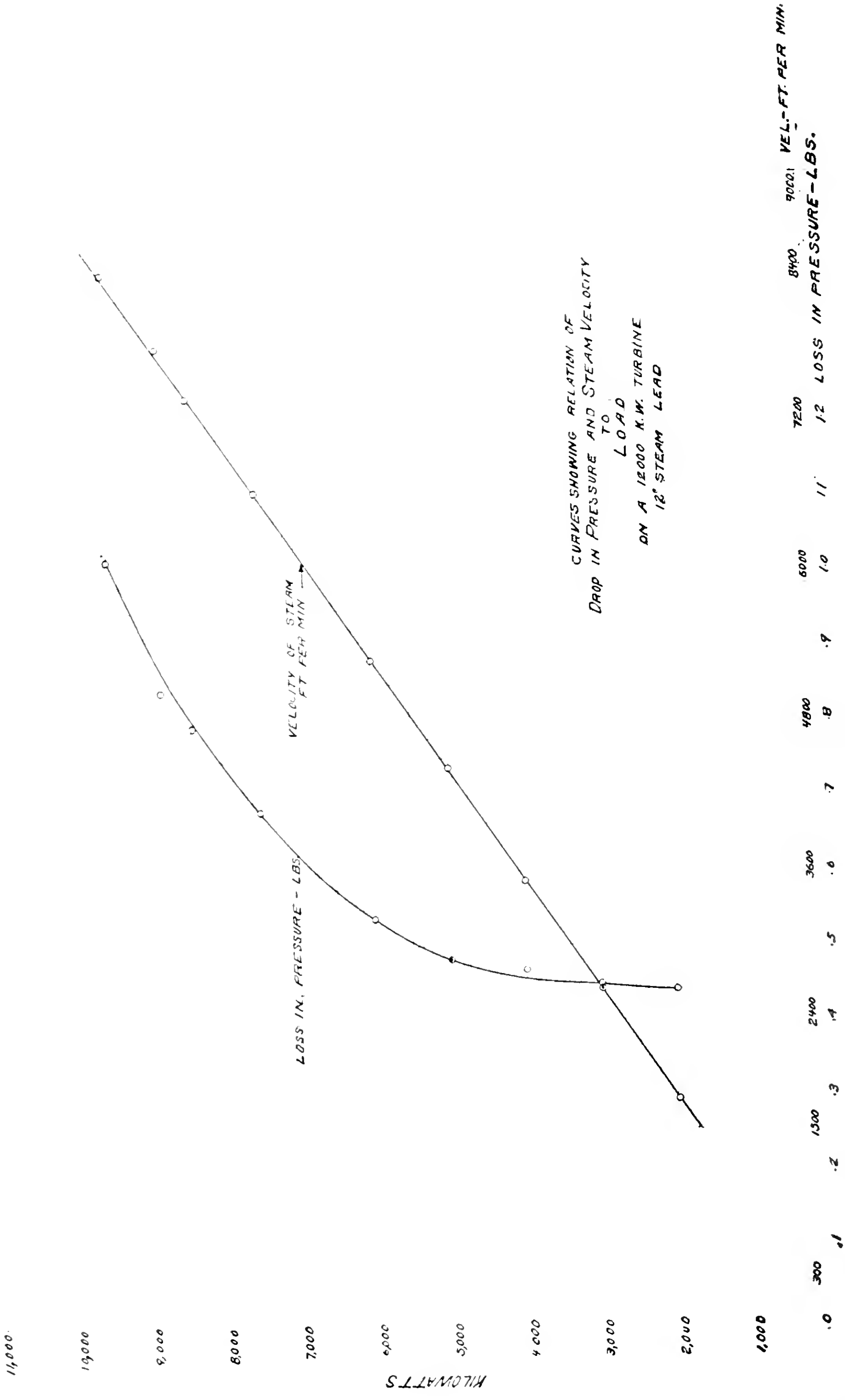

CURVES SHOWING RELATION OF
DROP IN PRESSURE AND STEAM VELOCITY
TO
LOAD
ON A 12000 K.W. TURBINE
12" STEAM LEAD
VELOCITY OF STEAM
FT PER MIN
LOSS IN. PRESSURE - LBS.
VEL.-FT. PER MIN.
LOSS IN PRESSURE-LBS.
KILOWATTS
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2
300 1500 2400 3600 4800 6000 7200 8400 9000.1

FIG. 9.

parts alone, this practically amounting to the weight of the valve. Another loss of 1.6 lb. per sq. in. was found where the steam passed through two 12-in. tees, one 12-in. angle valve and one 12-in. gate valve. These fittings were all close together and the direction of the steam was changed 90 degrees four times while passing through them.

Turbine Economy.

The displacement of large reciprocating engine units by the steam turbine is the most recent and most noticeable forward step in the history of the modern central power station.

The economy which is to be obtained in the use of steam turbines is marked. A given capacity of turbine apparatus not only costs less than the same capacity of reciprocating machinery, but there is great economy in the required outlay of capital for foundations and for buildings. The operating economy of large turbines is greater than that of the most carefully operated reciprocating units. The design of the turbine itself tends to high economy of steam consumption, while its simplicity and lack of many moving parts keep the cost of maintenance low.

Probably the point at which the most economy is to be gained in the actual operation of the modern steam turbine is in its condensing system. Here the effect of high vacuums is very marked. The steam consumption curve as it approaches absolute vacuum drops off rapidly. For this reason great economy is to be gained by careful attention to all details of operation and design tending towards higher vacuums. All central station operators are familiar with turbine conditions ordinarily necessary for maintaining high vacuums. Such points as keeping carbon rings and steam seals tight on middle bearings; keeping plenty of water on the seals of atmospheric relief valves and on the wet vacuum pump glands; maintaining tight joints around condensers and supplying plenty of cool circulating water; — these need no more than to be mentioned. There are, however, several no less important though perhaps less conspicuous points in condenser operation that may not have been brought to the attention of some.

High vacuums are temporarily reduced by cutting in fresh boilers on the steam header. This is apt to occur when the unit is most heavily loaded, with dry vacuum pump working up to capacity, hence has a decided effect on economy. That a fresh boiler passes a considerable quantity of air into the steam header on being put on the line was very forcibly brought out in a recent

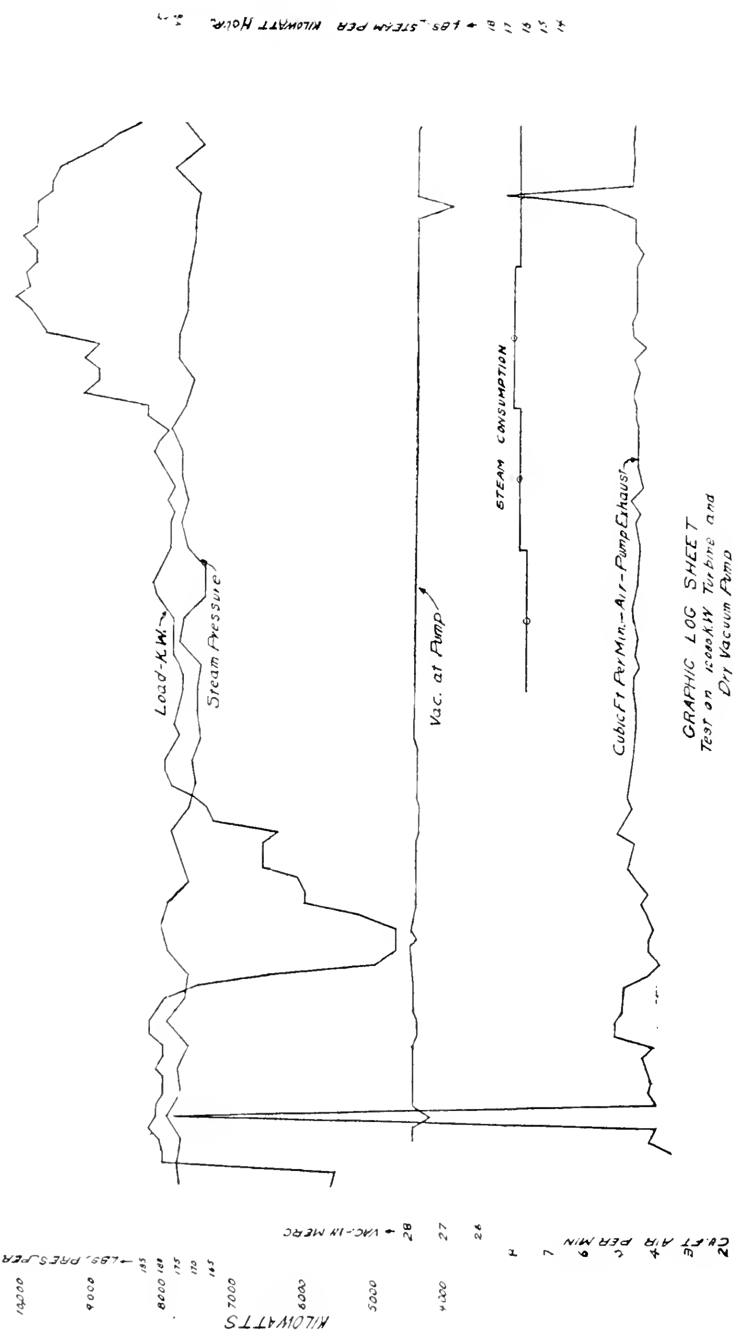

LBS. STEAM PER KILOWATT HOUR
Load-K.W.
Steam Pressure
Vac. at Pump
STEAM CONSUMPTION
Cubic Ft Per Min.-Air-Pump Exhaust
GRAPHIC LOG SHEET
Dry Vacuum Pump
KILOWATTS
LBS. PRES. PER SQ. IN.
VAC.-IN MERC
CU. FT. AIR PER MIN

Fig. 10.

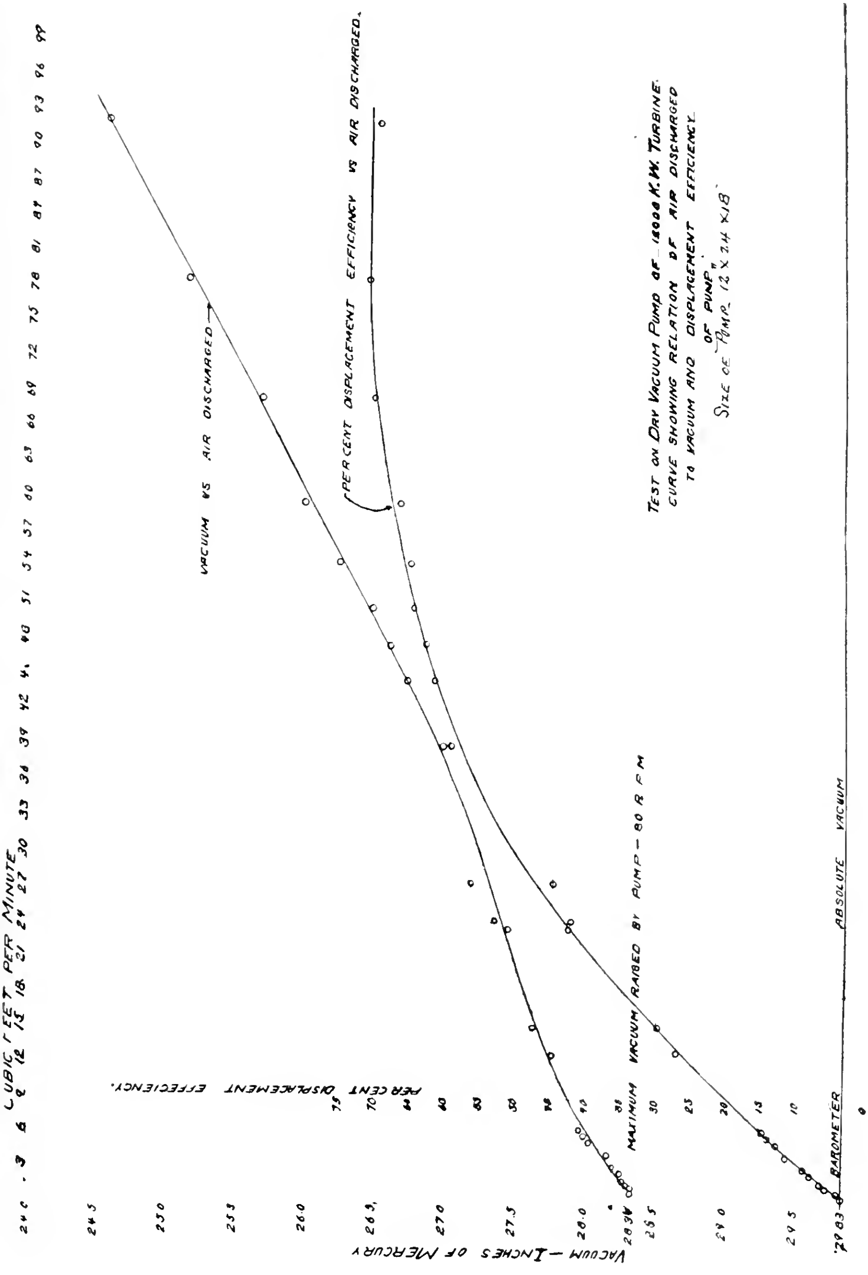

CUBIC FEET PER MINUTE
VACUUM — INCHES OF MERCURY
PER CENT DISPLACEMENT EFFICIENCY.
VACUUM VS AIR DISCHARGED
PER CENT DISPLACEMENT EFFICIENCY VS AIR DISCHARGED.
TEST ON DRY VACUUM PUMP OF 18000 K.W. TURBINE
CURVE SHOWING RELATION OF AIR DISCHARGED
TO VACUUM AND DISPLACEMENT EFFICIENCY
OF PUMP.
SIZE OF PUMP 12" x 24" x 18"
MAXIMUM VACUUM RAISED BY PUMP — 80 R P M
ABSOLUTE VACUUM
BAROMETER

FIG. 11.

series of tests on a 12 000 kw. unit. Here readings were taken on a special apparatus attached to the air exhaust of the dry vacuum pump.

This apparatus was designed to measure the exact volume of air that was delivered by a Worthington 12-in. by 24-in. by 18-in. air pump under all conditions. To accomplish this, a heavy wooden box of about 20 cu. ft. capacity, reinforced with tee irons, and airtight, was attached to the 8-in. exhaust of the air pump. On one end of the box, covering an opening some 3 in. in diameter, was an iron plate tapped in the center to receive a 2-in. plug. Knife-edged orifices, varying in size from $\frac{1}{4}$ to $1\frac{1}{4}$ in. in diameter were then made up, each from a 2-in. plug. These orifices could be easily changed when the amount of air from the pump increased or decreased the pressure in the box by too great an amount. This pressure was usually maintained at about $\frac{1}{2}$ to $\frac{3}{4}$ lb. per sq. in. during a test. By means of one of these orifices of known area and a U-tube which indicated inches of water pressure inside of the box, along with complete records of all temperatures, barometric pressures, speeds, etc., very accurate measurements were obtained of the volume of air delivered by the pump. Occasionally during the tests, and for no apparent reason, the vacuum on the condenser would begin to fall and the volume of air from the dry pump would increase rapidly. This would continue four or five minutes, when the vacuum would begin to rise and conditions gradually return to their former state. This condition was finally traced to the cutting in of fresh boilers in the boiler room. Figs. 10 and 11 show two such instances along with some other conditions and some of the results of a test. Because of this effect on the vacuum, care is always taken not to cut in fresh boilers at the peak of the load. Better economy is possible where the extra boilers needed for the peak can be put on the line a little early and brought up to the required capacity as needed.

Tight Condenser Tubes.

The effect of tight condenser tubes on station economy where river water is used for cooling is another important point in turbine operation. Conditions incident to operation often loosen the ferrules on the ends of the tubes and small water leaks will be set up between the circulating water and the condensation. Another source of leak is found in the pitting of the tubes. This action is apt to take place in any condenser, but is most marked in those units which are in service only a part of

the time. The cause of this pitting action is explained thus: Small negatively charged electric particles, such as bits of carbon or oxide of iron, coming in with the circulating water, will adhere to the side of the tube and set up local galvanic action at the expense of the zinc in the tube. This once started means spots of copper from which the zinc has been removed, and at such points the action goes on until there is a hole. The non-homogeneity of the alloy (70 per cent. copper, 30 per cent. zinc) composing most condenser tubes, is no doubt largely responsible for this pitting. Almost every tube where pitting has been found has contained streaks of both copper and zinc where the metals have not blended properly.

This condenser leakage has little effect on the steam consumption of the turbine unit, but going directly into the hot-well along with the condensation, it may be of such an amount as to change an otherwise soft and neutral hot-well supply into a highly alkaline and undesirable boiler feed-water. The practice at Ashley Street is to make frequent alkalinity tests upon the condensation of each unit, thus detecting the slightest leaks and remedying them before they become serious.

The number of passes which a condenser may have will sometimes be governed by local circulating water conditions. At the Ashley Street Station the circulating water at times contains large quantities of fine straw, rubbish, etc., part of which will invariably go through the intake screens. This obstructed the ends of the tubes of the three pass condensers so quickly that it was found necessary to cut out the baffles, leaving only the single pass. Although this does not remedy the condition it extends the intervals between the necessary clean-outs.

Engine Economy.

Efficiency in compound reciprocating units is not increased by extremely high vacuums to the same extent as on turbine units. Here certain other conditions of operation seem to have as great an effect on economy. Proper adjustment of valves with load evenly distributed over each cylinder; receiver pressures carefully regulated; and above all thorough lubrication of bearing surfaces, — these all have their effect on the economy of the unit. Careful and frequent use of the indicator is essential where high economy is to be obtained.

A plant operating both turbine and engine units often does not have load enough during a large part of the day to give full rated load to either kind of unit. Here the question of economy comes in as to where best to place the load. Load conditions

and the relative operative economy of the individual units are the first consideration. Engine units whose condensation contains too much oil for further use in the hot-wells will hardly be run with economy equal to that of the turbine unit which consumes the same amount of steam per kw. hr. and can return its condensation to the hot-well to be used again. On the other hand, auxiliaries from the engine units may be steam driven, and this additional exhaust steam may be necessary for maintaining the temperature of the feed-water in the heaters. Best economy may call for the operation of engine units. In a station where the main units are run condensing and where the feed-water heaters must receive their steam from the auxiliary exhaust system, it may not be good economy to operate electrically driven auxiliaries. In spite of the fact that power may be generated in the main units at 12 lb. of steam per h.p. hr. as against 60 lb. if generated on steam auxiliaries, the heat in the exhaust steam from the auxiliaries will be so taken up and utilized in the feed-water heaters as to make the economy of steam-driven auxiliaries over electrically driven 34 per cent. But, if live steam sufficient to heat the feed-water be taken from the receiver of a compound reciprocating engine or from the second stage of a turbine unit, and put directly into the heaters, the heat energy thus recovered will be far in excess of the expenditure necessary for electric auxiliaries.

As a matter of fact, a plant which has both turbine and engine units, with both steam and electrically driven auxiliaries, will operate both kinds of units, obtaining that economic balance throughout the station that permits all considerations of economy to receive their proper attention, while no one is worked to the limit at the expense of the others. When it is considered that in some plants 45 per cent. of the possible generating capacity is non-productive during sixteen hours of the day, this question of the economical distribu'ion of loads assumes some importance.

A modern central power station in its many phases represents a large and varied field for the application of practical points in economy. A more intensely interesting field of endeavor would be hard to imagine. The points brought out in hits paper are a few of the many that are constantly presenting themselves, and it is hoped that some of them may be suggestive of possibilities along the line of economy to those intimately connected with this sort of work.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1911, for publication in a subsequent number of the JOURNAL.]

THE USE OF THE SALINOMETER IN STUDIES OF SEWAGE DISPOSAL BY DILUTION.

By Kenneth Allen,* Member of the American Society of Civil Engineers.

[Presented to the Sanitary Section of the Boston Society of Civil Engineers.]

In planning sewer outfalls the engineer is confronted with questions regarding the probable sedimentation, diffusion and surface indications of the effluent, and the putrefactive conditions that may result from any given point of discharge. There is very little that can be predicted with certainty regarding these matters, which depend upon such variable factors as the composition and temperature of the sewage and the water into which it is to be delivered, their relative velocities, etc.

It is natural and proper to turn to the chemist, the bacteriologist and the biologist in this dilemma, to assist in the solution of problems of this kind, but much may be done by the engineer himself, who is not versed in any of these lines of investigation, by means of simple specific gravity determinations made with a hydrometer or "salinometer," as it is called when used for salt or brackish waters.

The instrument generally used by the United States Coast and Geodetic Survey for this purpose is the "Hilgard Ocean Salinometer." In form it is merely a carefully made hydrometer consisting of a weighted glass bulb with a slender stem, about one-eighth inch in diameter, which bears a graduated scale a little over three inches long (Plate I). A set of these adapted for use in waters varying from nearly fresh to those having the full salinity of the ocean comprises three instruments whose scales are divided for specific gravities of from 1.005 to 1.016, from 1.010 to 1.021 and from 1.020 to 1.031, respectively. Each graduation of the scale marks a difference in specific gravity of 0.0002.

The graduation is correct only when the water has a temperature of 60 degrees fahr.

In making a specific gravity determination, therefore, the sample of water is collected in a copper cylinder carrying a thermometer so arranged that it may be read while immersed, and then warmed or cooled until reaching 60 degrees, when the salinometer is immersed and read.

* Engineer, Metropolitan Sewerage Commission, New York.

For field use this instrument has proved inconvenient, fragile and expensive. A modified form was designed for the investigations of the Metropolitan Sewerage Commission of New York* in which the three hydrometers and thermometer of the Hilgard type are combined in one instrument, much stronger and much less costly.† This is twelve inches long with a stem $\frac{5}{32}$ inch in diameter, carrying a 4-in. scale reading specific gravities from 1.000 to 1.030. It is graduated to differences in specific gravity of 0.0005. The thermometer is inclosed in the bulb below the stem.

In use this is immersed in an ordinary glass cylinder, the hydrometer and thermometer scales read and a corresponding temperature correction applied.

To determine the amount of this correction solutions of varying salinity were prepared and their specific gravities at 60 degrees fahr. noted. These were heated to 80 degrees and then cooled to 32 degrees, noting the readings at different points, and the results averaged, tabulated and plotted in the form of a diagram.‡

The results are shown in the following table:

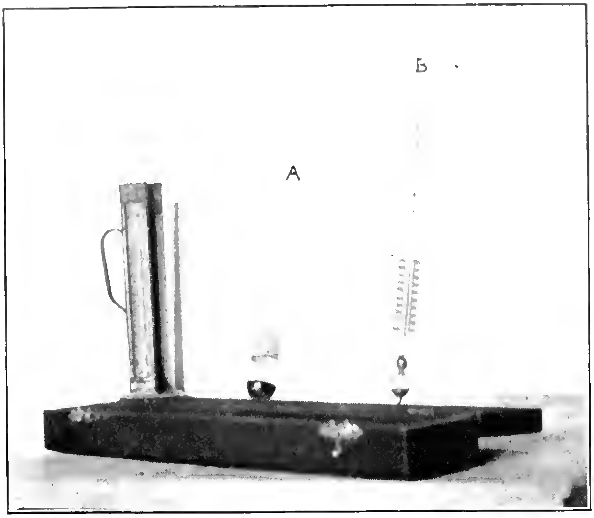
Temperature Corrections in Thousandths of Units.

Temp. Fahr.	Correction.	Temp. Fahr.	Correction.	Temp. Fahr.	Correction.
28	−0.9	47	−0.9	66	+0.6
29	−0.9	48	−0.8	67	+0.7
30	−1.0	49	−0.8	68	+0.9
31	−1.0	50	−0.7	69	+1.0
32	−1.1	51	−0.7	70	+1.1
33	−1.1	52	−0.6	71	+1.2
34	−1.1	53	−0.5	72	+1.4
35	−1.1	54	−0.5	73	+1.5
36	−1.1	55	−0.4	74	+1.6
37	−1.1	56	−0.3	75	+1.8
38	−1.1	57	−0.3	76	+1.9
39	−1.1	58	−0.2	77	+2.1
40	−1.1	59	−0.1	78	+2.2
41	−1.1	60	0.0	79	+2.4
42	−1.1	61	+0.1	80	+2.5
43	−1.0	62	+0.2	81	+2.7
44	−1.0	63	+0.3	82	+2.8
45	−0.9	64	+0.4		
46	−0.9	65	+0.5		

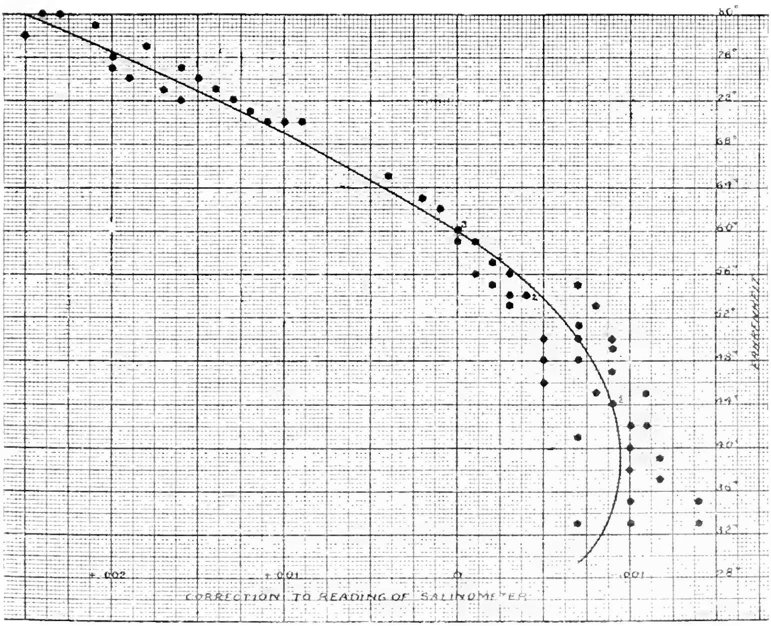
* George A. Soper, president; James H. Fuertes, secretary; H. de B. Parsons, Charles Sooysmith and Linsley Williams.

† These were made by the Emil Greiner Company, of New York.

‡ Corrections to 60 degrees fahr. may be found in Rep. U. S. C. & G. S., 1874, p. 155, and corrections to 15 degrees cent. (59 degrees fahr.) in Rep. U. S. C. & G. S., 1891, Appendix 6.



A. Hilgard Salinometer.
B. Metropolitan Sewerage Commission Salinometer.



There is also a slight variation in the temperature correction dependent on the salinity, but this is so small that it may generally be disregarded. The curve shown on Plate II represents a mean of observations made with salinities corresponding to specific gravity 1.000 and specific gravity 1.025.

In referring to mixtures of sea water and upland water it is convenient to fix on some standard salinity which shall be assumed as that of undiluted sea water. Such a standard must necessarily be arbitrary as the salinity of the ocean is different in different places. For example, the specific gravity (which depends on the salinity) of the Mediterranean Sea has been found to be about 1.029,* and that of the Atlantic Ocean:

Gulf Stream	1.028
North of the Azores	1.027½
120 miles from Nantucket	1.027½
40 miles off Cape Ann	1.025¼
Off Cape Cod	1.024½
Between Nantucket and Cape Henlopen	1.024
12 miles off Long Branch, N. J.	1.024
12 miles off Long Branch, N. J., at depth of 150 ft.	1.025
Off Sandy Hook	1.023½
Off Cape Elizabeth, Me.	1.022⅓

In general it may be said that the specific gravity of the ocean off New York Harbor is about 1.025, which closely corresponds to a chlorine content of 18 000 parts per million (assuming that chlorides represent 88.6 per cent. of the total excess in specific gravity above 1.000), and this value was assumed in the investigations of the Metropolitan Sewerage Commission as a standard. To find the percentage of sea water in any mixture, therefore, it was only necessary to multiply the first three figures to the right of the decimal point in the corrected specific gravity reading by 4. Thus, if the reading were 1.016 it indicated a percentage of sea water of 16 by 4 = 64. With the type of salinometer adopted for the work the resulting error in the determination of sea water was probably less than two per cent.

One application of the salinometer is in questions relating to stream flow. The following is an illustration of a case where, owing to local conditions, it was possible to draw important conclusions from the work of two days and at a nominal expense.

From various current meter and float observations made by the United States Coast and Geodetic Survey in the past it has

* Rep. Addl. Water Supply for City of New York. Burr-Hering-Freeman, 1903, p. 517 *et seq.*

been very generally supposed that there was a resultant southerly tidal flow from Long Island Sound through the East River to New York Upper Bay of about 11 per cent. of the flow in the opposite direction, or about 400 million cu. ft. per tide. On reviewing the whole question for the Metropolitan Sewerage Commission, two or three years ago, the superintendent of the Survey, Mr. O. H. Tittman, reversed the opinion previously held by them, maintaining that "it can hardly be said that our observations upon the currents indicate a net discharge in either direction through Hell Gate." At most, he believes the southerly excess will not greatly exceed one per cent., or about 40 million cubic feet per tide.

PLATE III

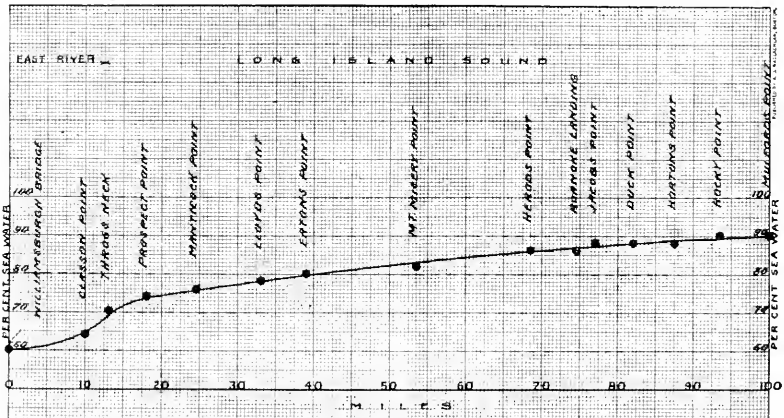


DIAGRAM SHOWING INCREASE IN SALINITY IN GOING EASTWARD FROM NEW YORK THROUGH LONG ISLAND SOUND

It is a matter of considerable importance in estimating the capacity of New York Harbor to receive and dispose of increasing volumes of sewage, whether the waters are being constantly replenished from the Sound and discharged through the Narrows to the ocean, or not. Although floats generally made some progress in this direction, one set adrift about five miles east of Hell Gate drifted back and forth between this point and Brooklyn Bridge for 3 days 6.5 hours, having traveled nearly 108 miles, and was taken out about two miles from the starting point, confirming the view that there is no net discharge in either direction.

A gaging to definitely settle the question would be exceedingly costly in a strong tidal stream filled with ferries, yachts, car floats, tugs, etc., but the fact that such a resultant flow does exist

was shown by the use of the salinometer in observing the decrease in salinity of Long Island Sound and the East River in passing through the former from its eastern end and then through the East River to Upper New York Bay. The percentage of sea water observed was 90 at Greenport, 70 at Throgs Neck, 60 at Williamsburg Bridge and but 35, where influenced by the Hudson, at Governor's Island. By reference to the accompanying diagram it will be seen that the salinity remained high until passing Hell Gate, while if the waters of the sound were derived from the upper bay the salinity near the westerly end would probably not greatly exceed the 35 per cent. at Governor's Island.

This result received confirmation by determinations of dissolved oxygen and bacteria. The former decreased from an average of 99 per cent. of saturation in the Sound to 86 in the Upper East River, 65 in the Lower East River and 67 in New York Upper Bay, while the average number of bacteria per cu. cm. increased from 375 in the Sound to 3 400 in the Upper East River, 8 700 in the Lower East River and 14 500 in the Upper Bay. These figures are averages from large numbers of samples from which those obviously polluted from nearby sources have been excluded.

By a series of observations, long enough to eliminate fluctuations due to tidal and other influences, we may determine the normal proportion of sea water in a tidal stream or estuary. Such observations were made at 11 stations by the Metropolitan Sewerage Commission, located in waters comprised between Tarrytown on the Hudson, Throgs Neck at the entrance to Long Island Sound, Ambrose Light Ship just outside Lower New York Bay, Great Beds near the head of Raritan Bay and Passaic Light in Newark Bay (Plates IV, V). The work was done through the courtesy of the United States Lighthouse Board and was in direct charge of Mr. D. S. Merritt. The plotted results of readings taken at 8 A.M., noon and 4 P.M., at each station throughout the year 1909, and averaged every five days, to comprise all stages of tide, show very graphically the marked difference of salinity between the waters of the Hudson and Newark Bay and those of Throgs Neck and at Ambrose Lightship, ranging from yearly averages of 14.7 to 92.4 in the percentage of sea water. They also show the seasonal effect of freshets in the Hudson, the variations due to the ebb and flood tides and those from other causes.

The practical value of studies of salinity lies partly in the fact that the buoyancy, or tendency to rise to the surface without

PLATE IV

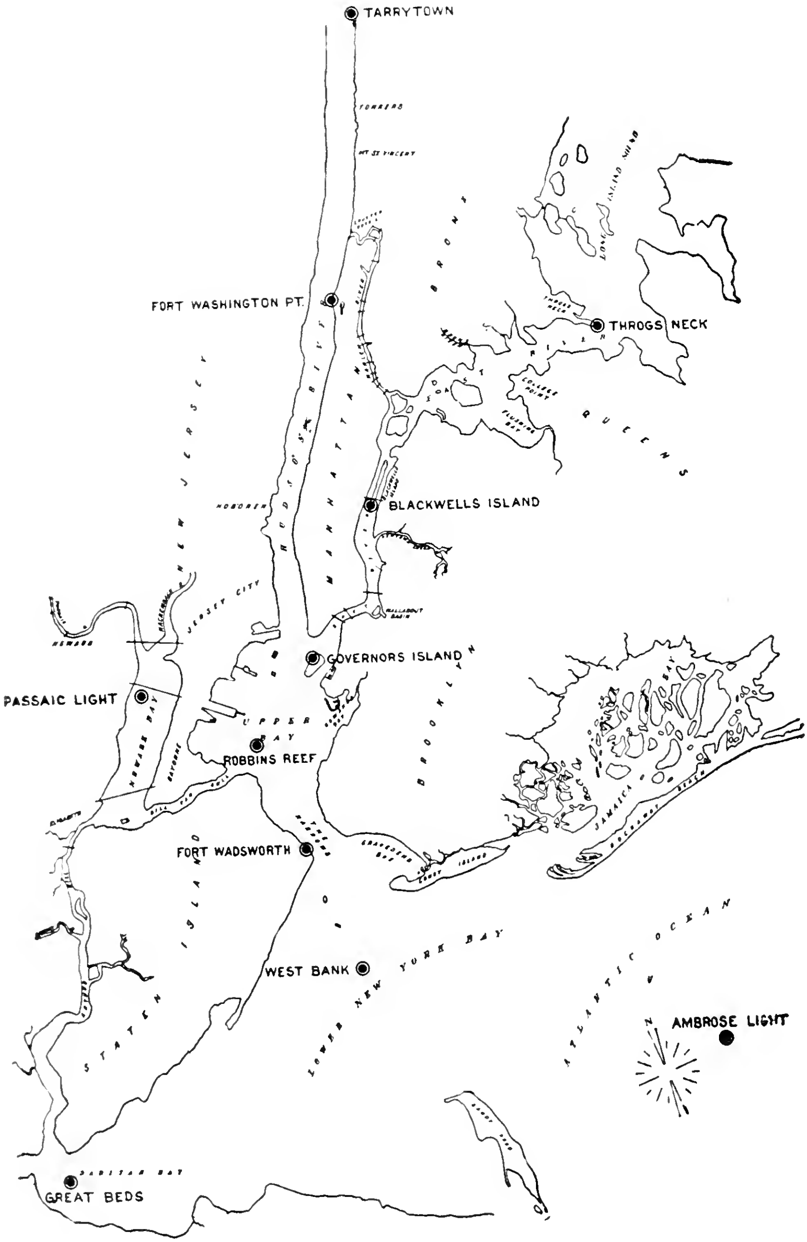
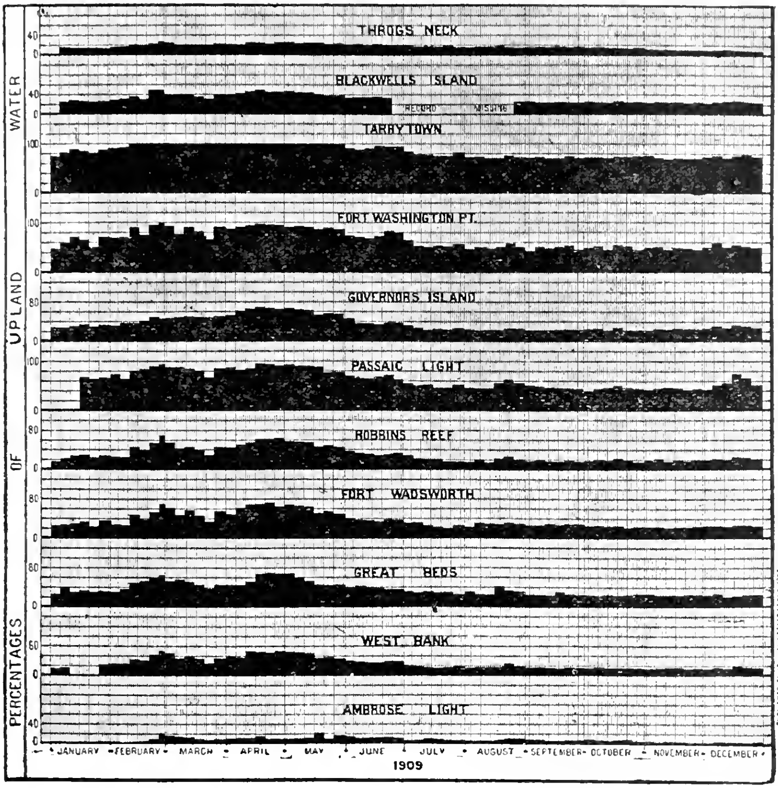

TARRYTOWN
FORT WASHINGTON PT.
THROGS NECK
BLACKWELLS ISLAND
GOVERNORS ISLAND
PASSAIC LIGHT
ROBBINS REEF
FORT WADSWORTH
WEST BANK
AMBROSE LIGHT
GREAT BEDS
N E W J E R S E Y
JERSEY CITY
HOBOKEN
NEWARK
NEWARK BAY
BAYONNE
H U D S O N R I V E R
M A N H A T T A N
B R O N X
Q U E E N S
B R O O K L Y N
U P P E R B A Y
S T A T E N I S L A N D
L O W E R N E W Y O R K B A Y
A T L A N T I C O C E A N
JAMAICA BAY
ROCKAWAY BEACH
CONEY ISLAND
GRAVESEND BAY
SANDY HOOK
RARITAN BAY
LONG ISLAND SOUND
COLLEGE POINT
FLUSHING BAY
WALLABOUT BASIN
N

PLATE V.



From Rep. Met. Sew. Com., Apr. 30, 1910.

RESULTS OF FIVE DAY AVERAGES OF SALINOMETER OBSERVATIONS MADE IN NEW YORK HARBOR IN 1909 BY THE METROPOLITAN SEWERAGE COMMISSION OF NEW YORK.

mixing, of sewage effluents depends very largely on the salinity of the water and that with an increase of salinity there is a greater tendency to precipitate the solids. This tendency is partly due to chemical changes and partly to the physical inability of highly saline waters to carry the same weight of material in suspension as fresher waters.

Sewage discharged from a submerged outlet will rise toward the surface at a rate dependent on the relative specific gravity of the two liquids. If the water is warm and fresh, the sewage will remain near the bottom, but under ordinary conditions it will rise and its rate of ascent is found to be largely dependent on the salinity of the water.

To gain information as to this matter, croquet balls were bored, carefully weighted with shot, varnished and adjusted until of specific gravity 1.000. Each ball carried a small screw-eye by which it was fastened with a short thread to an endless cord running through two small galvanized pulleys. One of these pulleys was lowered from a boat to a specific depth, such as 10 ft., and the cord pulled until the ball reached the lower pulley and the ball was released by the breaking of the thread. The time of the ball's ascent to the surface was then noted by a stop-watch.

The experiments were not carried far enough to furnish precise results, but the following round figures were deduced from fifty-three trials:

Difference in Specific Gravity between Ball and Water.	Velocity of Ascent, Feet per Second.
0.007	0.25
0.009	0.30
0.016	0.45
$0.021\frac{1}{2}$	0.50

A very slight difference in the smoothness or shape of an object was found to have a marked effect on the resulting velocity. This was observed in forty-two experiments carried out in a similar way, but using bottles and tin cans as well as balls whose weights were adjusted to specific gravity of unity. For instance, in water of 1.0215 specific gravity, bottles rose with an average speed of 0.72 ft. per second, wooden spheres with an average speed of 0.49 ft. per second, and a tin cylinder at 0.42 ft. per second.

Although the results were not always consistent, the influence of smoothness and shape, as well as relative specific gravity, was demonstrated. It is probable, too, that the temperature of the water, which affects its viscocity, is an important factor; but the experiments were not extended to determine this.

Now, when one liquid is discharged into another below the surface, it immediately begins to diffuse in it, and to the extent of this diffusion it loses its identity; that is to say, a mixture of the two is formed, partaking of the characteristics of each. The more rapid the mixing, therefore, the sooner the buoyant effect due to the difference in specific gravity is lost. If a large volume of sewage were discharged with a low velocity into still water, mixing would take place gradually and the center of the mass might rise to the surface with a velocity approximately that of a solid sphere. Under other conditions the motion would be slower.

A large number of experiments were made by the Metropolitan Sewerage Commission by discharging colored water or sewage at different depths up to 62 ft. below the surface in waters of different densities and noting the result. These were not always harmonious, due to the varying conditions of the current and other causes; but in general, where the injected water was of a specific gravity from 0.004 to 0.016 less than that of the harbor water and the depth of discharge was between 20 and 40 ft., its rate of ascent was from 0.10 to 0.17 ft. per second, or about one third the rate that would obtain with solid spheres of like specific gravity.

Knowing the depth of discharge, the velocity of the current and the relative specific gravity of the sewage and the stream, a rough estimate may be readily made of the distance from the outlet at which the sewage may be expected to reach the surface.

Assuming, provisionally, that the rates given above for spheres are correct and that the sewage will rise at one third these rates, this distance would be

$$X = \frac{CD}{V},$$

in which

X = distance to point where sewage appears on the surface.
C = velocity of current.
D = depth of discharge.
V = upward velocity of sewage.

TABLE. Horizontal Distance from an Outlet Submerged 20 Ft. below the Surface at which Effluent will Appear in Different Currents.

Difference in Sp. Gr.	Velocity of Ascent, Ft. per Sec.	Velocity of Current Feet per Second.								
		0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0.005	0.06	0	167	333	500	667	833	1 000	1 167	1 333
0.010	0.11	0	91	182	272	363	455	545	635	725
0.015	0.15	0	67	133	200	266	333	400	466	533
0.020	0.167	0	60	120	180	240	300	360	420	480

If the stream or estuary discharges through a channel such that the volumes passing out on the ebb and in on the flood can be estimated, and if we know the volume of upland water that

passes out on each tide, we may calculate the new sea water that enters during each flood tide to assist the upland water in replenishing the supply of dissolved oxygen required to aid in its purification.*

Applying this to the case of Upper New York Bay and assuming that the normal proportion of sea water is there 62.5 per cent.:

Let E = water passing out in a tidal cycle of 12 lunar hours = 12 310 million cu. ft.

R = upland water discharged by the Hudson River in 12 lunar hours = 1 180 million cu. ft.

S = average proportion of sea water passing out in the ebb through the Narrows = 62.5 per cent.

Then the volume of upland water passing out with the ebb will be $E(1-s)$ = 4 617 million cu. ft.

The proportion of the upland water that will remain outside and not return $= \dfrac{R}{E(1-s)} = 25.6$ per cent.

Assuming that, of the entire ebb discharge, this proportion remains outside, we have:

Upland water that remains outside = 37.5 per cent. of 25.6 per cent. = 9.6 per cent. =	1 180 million cu. ft.
Sea water that remains outside = 62.5 per cent. of 25.6 per cent. = 16.0 per cent. =	1 970 million cu. ft.
Upland water that returns to Upper Bay = 37.5 per cent. − 9.6 per cent. = 27.9 per cent. =	3 435 million cu. ft.
Sea water that returns to Upper Bay = 62.5 per cent. − 16.0 per cent. = 46.5 per cent. =	5 725 million cu. ft.
Total volume of ebb discharge,	12 310 million cu. ft.

The estimated volume of the flood discharge through the Narrows to the Upper Bay is 11 030 million cu. ft. Of this there passed out on the previous ebb:

Upland water,	3 435 million cu. ft.	= 31.1 per cent.
Sea water,	5 725 million cu. ft.	= 51.9 per cent.
Total,	9 160 million cu. ft.	
The sea water entering for the first time is, therefore, 11 030 − 9 160 =	1 870 million cu. ft.	= 17.0 per cent.
Total,		100.0 per cent.

* See discussion by Allen Hazen, in Journal of the Association of Engineering Societies, June, 1906.

In a similar manner, during the conditions which prevail in dry weather, when the flow of the Hudson River is reduced to 623 million cu. ft. in twelve lunar hours and the proportion of sea water in the Upper Bay rises to 77 per cent.:

The volume of upland water that remains outside =	616 million cu. ft. =	5.0 per cent.
The volume of upland water that returns on the flood =	2 216 million cu. ft. =	18.0 per cent.
The volume of sea water that remains outside =	2 092 million cu. ft. =	17.0 per cent.
The volume of sea water that returns on the flood =	7 386 million cu. ft. =	60.0 per cent.
Total volume of ebb discharge,	12 310 million cu. ft.	100.0 per cent.

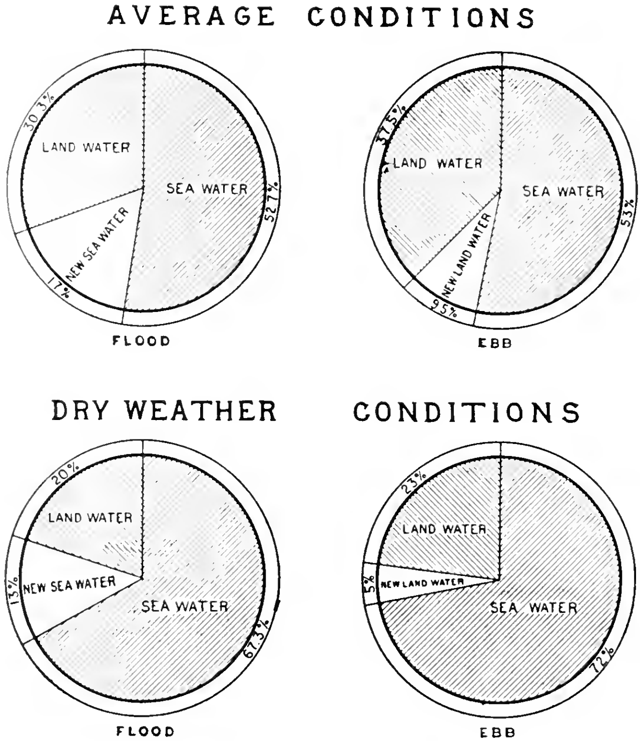
And of the flood:

The volume of upland water brought down by the previous ebb =	2 216 million cu. ft. =	20.1 per cent.
The volume of sea water entering for the first time =	1 428 million cu. ft. =	12.9 per cent.
The volume of sea water that had entered before =	7 386 million cu. ft. =	67.0 per cent.
Total volume of flood discharge,	11 030 million cu. ft.	100.0 per cent.

These results, with a slight difference in the assumed salinity of the Upper Bay, are shown graphically in Plate VI.

It will be seen that, unfortunately, during those dry periods when the supply of fresh upland water falls from 1 180 to 623 million cu. ft. in a tidal cycle, the volume of new sea water entering on the flood current is also diminished from 1 870 to 1 428 million cu. ft. in a tidal cycle, cutting off the supply of dissolved oxygen from both sources. In other words, while under ordinary conditions the volume of the Upper Bay, which is about 12 970 million cu. ft., is replenished by 1 180+5 725 = 6 905 million cu. ft., of upland and new sea water, or 53.2 per cent. in a tidal cycle, in times of drought this is reduced to 623+1 428 = 2 051 million cu. ft., or 15.8 per cent. The available oxygen, however, is not reduced to this extent, for absorption from the atmosphere is continually taking place. This, and the process of sedimentation, combine to relieve the water of a portion of its burden of pollution and should be taken into consideration, remembering at the same time that *organic* matters deposited on the bottom continue to draw on the water for oxygen in their reduction to mineral

Plate VI.



Proportions of Sea Water and Upland Water at the Narrows.

compounds for long periods. Indeed, this may constitute an important and, in many cases, unsuspected source of pollution in streams or estuaries receiving sewage.

With increasing densities of population and the consequent fouling of our rivers and bays, the necessity for a rational treatment of the sewage disposal problem will be more and more felt, and a greater discrimination than in the past will be made in the treatment of each individual case as it arises. And among the several approved methods adapted to as many different conditions, disposal by clarification with subsequent dilution is probably destined to play a prominent part, especially in large seaport towns. But, in order to satisfy the requirements of the public regarding pollution in the best and most economical way, more careful consideration of such matters as the direction, volume and velocity of the currents, the salinity and temperature of the water and the character of the sewage — especially as to the suspended and floating solids, grease, etc. — will be re-

quired. It is especially in studies of this kind that the salinometer may be found useful to the engineer.

In conclusion, the author desires to acknowledge the careful salinometer work of Mr. D. S. Merritt, engineer, and Dr. P. B. Parsons, bacteriologist, of the Metropolitan Sewerage Commission, the results of which form the basis of this paper.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1911, for publication in a subsequent number of the JOURNAL.]

DETROIT RIVER IMPROVEMENT.

By Charles Y. Dixon, Member Detroit Engineering Society.

[Read before the Society, February 17, 1911.]

The improvements of channel and harbor facilities for navigation purposes by the United States are made with the view to reducing the cost of transportation. Statistics show that the total cost to the United States of river and harbor improvements on the Great Lakes from their inception is less than the present direct annual saving in cost of transportation resulting from such improvements. The saving thus made affects directly the cost of living not only for those who live in the vicinity of the Great Lakes, but also in a less degree for those who live remote from them.

The amount of commerce now traversing the Great Lakes is not appreciated by those not in direct contact with it, and one would hesitate to predict its future growth. This traffic has increased from a few small schooners and a still less number of steam vessels of fifty years ago, whose movements were largely dependent upon the weather, until now there is more tonnage passing through the Detroit River than passes along any other route in the world. During the season of 1909 the amount of this commerce was nearly 68 000 000 tons, much of which was carried in vessels from 500 to 600 ft. or more in length with a capacity of from 7 000 to 12 000 tons.

The improvements of channels and harbor facilities have not kept pace with this commercial development; in fact, many of these improvements have not been undertaken until their necessity was imperative. It is the purpose in this paper to give a brief outline of the work done in lower Detroit River, and to describe briefly some of the methods employed.

Prior to improvement, the main channel at Limekiln Crossing in lower Detroit River was near the Canadian shore as it is now, and here the navigable depth was limited to about 12 ft. by a ledge of limestone. In 1874 the first improvement was made in this locality with only a small appropriation available. This was followed by other work under small appropriations until 1888, when this portion of the channel was completed to 440 ft. width and to 20 ft. depth at the prevailing midsummer stage of

water, or to about 18 ft. depth at the low water datum since assumed as the plane of reference. When vessels were permitted a greater draft on account of this improvement, many other obstructions were found both north and south of Limekiln Crossing which still limited the navigable depth to about 16 ft. In 1892, a project for channel improvement on a much larger scale was adopted with the view to obtaining 600 ft. minimum width and 20 ft. navigable depth from Detroit to Lake Erie. In carrying out this project, it was necessary to remove bed rock, in places overlaid with earth and bowlders, for the greater part of a length of channel of about six miles; and to excavate earth and bowlders, but no bed rock, for about six miles further to deep water in Lake Erie. The project of 1892 was modified in 1902 to secure 600 ft. width and 21 ft. depth at a low-water stage, or a Lake Erie stage of 571 ft. above mean tide at New York. This modification of the 1892 project provided for about 3 ft. greater depth, and required the redredging of the areas already improved. The improvements under the 1892 project and its modification were continued each season until now there is a channel of 600 ft. minimum width and 21 ft. depth, except for a distance of about three miles north of Limekiln Crossing, where the channel has been improved to 600 ft. width and 19 ft. depth. In the latter locality, funds are available and work is in progress to secure its completion. The cost to the United States of improvements made as stated in the channel now in use in lower Detroit River is about $4 750 000.

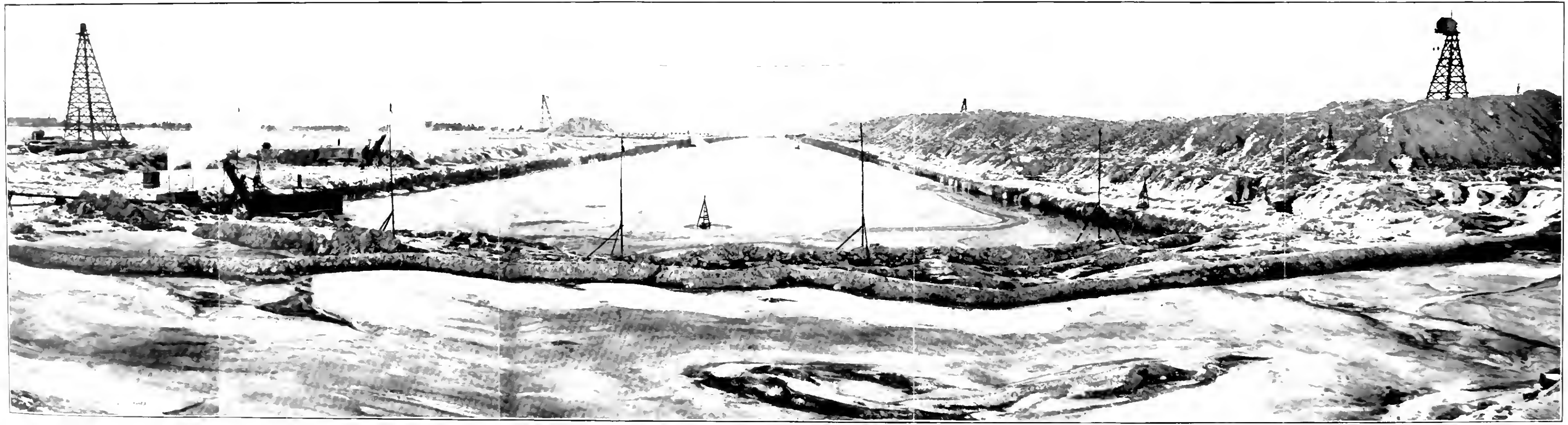
On account of the increasing number of large vessels on the Great Lakes, and on account of the dangers to navigation in narrow channels with swift currents and sides of jagged rock, the need for a second channel at the mouth of Detroit River became imperative, and in 1906 surveys were made to determine the route for such channel. The routes selected for examination and survey were three in number, as follows: One leaving the present channel about one mile north of Limekiln Crossing, thence straight to Detroit River lighthouse at the mouth of the river, passing east of Stony Island and west of Bois Blanc Island; a second leaving the present channel near the foot of Fighting Island, thence passing between Grosse Isle and Stony Island, and thence straight to Detroit River lighthouse; and a third leaving the present channel at the head of Fighting Island, thence through the shoal at Grassy Island and following the Michigan shore to the foot of Tawas Island, thence to Detroit River lighthouse. In making the selection of the route

for this second channel, that to the west of Grosse Isle was found to offer many advantages, but the first route mentioned was finally selected because the cost was less and it offered a straight course. In 1907 Congress appropriated funds for this improvement and authorized it to be known as the Livingstone Channel, in recognition of the many services rendered in the interests of navigation by the Hon. Wm. Livingstone.

This project provides for a depth of 22 ft. at a low-water stage; and for a channel width of 300 ft. for the north six miles, thence for 800 ft. width for six miles further to deep water in Lake Erie. The entire area was surveyed by taking soundings and borings to determine depths of water and character of material. The work was divided into four sections, the dividing lines being determined mainly by the character of material and the contour of the bottom; and, after due advertisement, contracts for the work under each of these sections were entered into with the lowest bidders. The work performed under these contracts is paid for on the basis of bank measurement of material removed, except for that at the Lake Erie end, or Section 4, where payment was made on the basis of scow measurement. These contracts are described more in detail as follows:

Section 1. — This area is 5 800 ft. long and 300 ft. wide. The material was mainly limestone bed rock of an average depth of about 4 ft. above the required grade. Payment was made at the contract price of $1.98 per cu. yd. for all material above 22 ft. depth, and at one half of that rate for material removed between 22 and 24 ft. depths. The amount of money involved in this contract was about $676 000.

Section 2. — This area is 7 500 ft. long and 300 ft. wide. The material was limestone bed rock which was overlaid with earth at the south end only for a length of about 3 500 ft. The contract required that at least 4 000 ft. length of this area near its north end should be inclosed by dams, the inclosed area unwatered, and excavation made in the dry. After the work was well under way, the contractors extended their dams to the northward of the 4 000 ft. length stipulated by the contract and inclosed an additional area of 300 ft. length at the north end of Section 2 and 1 500 ft. length at the south end of Section 1. The entire area thus finally inclosed by dams was 5 800 ft. long with an average width of about 1 200 ft., or about 160 acres. The prices paid for this work were as follows: Excavation required to be made in the dry, $1.24 per cu. yd. for rock and $0.60 for earth above 23 ft. depth; and one half of these prices for material



Livingstone Channel

removed between 23 and 24 ft. depths. Excavation outside of the required dry area, \$3.40 per cu. yd. for rock and \$0.60 for earth above 22 ft. depth; and one half of these prices for material removed between 22 and 24 ft. depths. A payment of \$25 000 was made for cofferdam construction after the inclosed area had been unwatered and kept dry for one month; and further payments of \$15 000 and \$5 000, respectively, will be made for the removal of so much of the dams and old railroad pier as crosses the channel and lies within 50 ft. of the side lines. The side walls were required to be channeled, but payment therefor is not made directly, as this is included in the price paid for excavation. The contract requires, however, that a deduction of \$0.50 be made for each square foot of channeled face of wall that may be broken or shattered as a result of the contractors' operations. The depth of rock cutting within the area finally inclosed by dams varied from 10 to 19 ft.; and for the south 4 000 ft. length, the average depth of rock cutting was about 17 ft.

In explanation of the prices paid under this contract, it may be stated that the cost of the dams was about \$100 000 and that they were built with material excavated from the channel outside of the inclosed area. The contractors evidently have added the cost of the dams to the cost of removing the outside material in order that they might obtain this money at an early stage of the contract. The total amount of money involved in this contract is about \$1 800 000, a saving of about \$700 000 over the usual subaqueous prices for such work.

Section 3. — This area is 18 250 ft. long and 300 ft. wide, except for the south 1 000 ft., where the width increases from 300 to 550 ft. The material was limestone bed rock with earth and bowlders overlying. The prices paid for this work are \$2.80 per cu. yd. for rock and \$0.50 for earth above 22 ft. depth, and one half of these rates for material removed from between 22 and 24 ft. depths. The amount of money involved in this contract is about \$2 834 000. The prices paid for this work would be regarded as too high were it not for the fact that much of the area is exposed to the heavy seas of Lake Erie, rendering rock drilling and blasting difficult and expensive.

Section 4. — This area is about 29 000 ft. long and 800 ft. wide, except for the north 1 000 ft., where the width decreases from 800 to 550 ft. The material was clay, sand, gravel, silt and some hardpan. The price paid for this work was $25\frac{1}{2}$ cents per cu. yd., scow measurement, for all material above 24 ft. depth; and no payment was made for excavation below that

depth. The amount of no pay material was determined from surveys following the completion of the work. The entire area was exposed to heavy seas. The amount of money involved in this contract was about $950 000.

The progress made on these several contracts is as follows: Sections 1, 2 and 4 are completed except for the removal of the material underlying the dams, and except for the removal of a few pieces of loose rock in the subaqueous portion of Section 2. At Section 3, about 75 per cent. of the rock and all of the overlying material have been removed, but no part of the area has been cleared to grade.

The total cost of this work will be about $6 270 000, or about $400 000 less than the amount of the preliminary estimate.

The Livingstone Channel project was begun under the direction of Colonel Davis, now General Davis; and continued and will be completed under the direction of Colonel Townsend, both of whom are members of this society.

It may be of interest to mention some special features in connection with the excavation in the dry. In this locality the dry method is particularly well adapted to the work, for the reason that the shoal water renders the cost of dam construction small as compared to the amount of material to be excavated. However, when the bids for the work were received, other contractors agreed that the successful bidders were taking desperate chances. There were necessary several months' work and an outlay of at least $100 000 on dam construction before any payments could be expected; should the material at hand for dams prove unsuitable, should underground seams in the rock be found, or should an unusually high stage of water flood the area when unwatered — in fact, many things were mentioned, any one of which meant a losing contract. But Grant Smith & Co. and Locher have carried their original contract practically to completion without serious loss from such causes, although such loss at times seemed imminent. They came to this work after having completed a contract involving similar work at West Neebish, in St. Mary River, and have been unusually alert and energetic, and prepared for all emergencies.

Construction of Dams. — The material for the dams consisted mainly of clay and bowlders, which were excavated from the channel outside of the area to be inclosed, for which excavation payment was made at the contract rate. This material was loaded on flat scows, the scows towed to the site of the dams by tugs and launches, and there unloaded by means of steam

scrapers. Later a small dredge was used to cast over some of the material on top of the dams. The details of the dams and the method of their construction were left entirely to the contractors, who were responsible for their maintenance. When building the north dams, a core of broken rock was first built to the water surface to break the force of the current, then other material was dumped over the rock to make the dam tight. Elsewhere, only clay and small bowlders were used. The dams have been unusually tight, very few leaks having developed, and only one or two of a serious nature. One serious break was threatened during the winter of 1909–10, when the ice covering the river rose with a high stage of water and caused a break near the top of the dam. This leak was soon under control and was closed entirely after about forty-eight hours of continuous labor.

Compressed Air Plant. — On this work, the entire plant was operated by compressed air, except the steam shovels and some of the pumps. The compressed air plant consisted of two compressors, one of 700 and one of 300 horse-power. When only a part of the plant was at work but one compressor was used. This permitted of each engine being kept in thorough repair. The air was delivered at about 90 lb. pressure, and on most of the plant it passed through reheaters before use. At times some trouble was caused by moisture freezing in the pipe lines, and during cold weather fires were always necessary under the pipes at angles or bends, particularly in the case of the smaller pipes. The main pipe for transmission of compressed air was of 8 in. diameter, and the air was distributed to the various portions of the plant through pipes of smaller sizes.

Channeling. — Prior to the rock being disturbed by drilling and blasting, the sides of the channel were cut from the rock, and made smooth and vertical by the use of channeling machines. For a length of about 2 500 ft. where the depth of cutting was greatest, the rock was taken out in two lifts of from 9 to 10 ft. each. At this locality the offset in the channeled wall was about 9 in., the minimum distance between the opposite walls being the required 300 ft. The machines were caused to travel forward and backward on tracks for a distance of about 10 ft., continually chopping the rock until the entire depth of cutting was made, then the track was moved forward. There were three channeling machines in use, each of which was operated by three men. The average rate at which the channeling was done was about 12 sq. ft. per machine per hour.

Drilling Plant. — At the beginning of the contract, the drilling plant consisted of a number of small portable tripod drills, the number in use varying from 10 to 16. After the contract was well under way, a new type of drill, designed by Mr. C. H. Locher and known as the traction drill, was used with extremely good results. The holes were usually drilled at the corners of from 6- to 8-ft. squares. For the tripod drills, it was necessary to change the bits for every two feet of depth, starting with a $2\frac{1}{2}$ in. hole and making the hole smaller by $\frac{1}{8}$ in. with every change of bit. The traction drill was designed to make a 5-in. hole of 16 ft. depth without changing bit. With the small tripod drill, the holes were made at an average rate of about 5.8 ft. per drill per hour; and with the traction drill the average rate was about 18.5 ft. per hour, or more than three times the rate of the small drill. The traction drill was designed to clear the hole more thoroughly from chips so that the blow becomes more effective. This was accomplished by means of a valve within the drill pipe through which the chips with water were forced at each blow. Each drill was operated by two men, and Mr. Locher has succeeded in making two men do six men's work without violating the eight-hour law. This new drill is being adapted to subaqueous work under the direction of Mr. Locher, and the result will eventually be a decided saving on this class of work.

Blasting. — After the holes were drilled they were loaded with dynamite and fired. Except in freezing weather, the blasting was done during meal hours when all other workmen were at a safe distance. Usually, two rows of holes were fired at a time, and this only for half of the channel width. At the time of firing, the steam shovel was placed along the farthest wall. The dynamite used was of the 60 per cent. and 40 per cent. grades, the latter being used near the side walls and near the top of deep holes. In shallow drilling, 60 per cent. dynamite only was used. The amount of dynamite used averaged 1.5 lb. per linear foot of hole, and 0.8 lb. per cu. yd. of material excavated. The contractors have been fortunate in the selection of careful men for this work, and on this contract no accident of any kind has resulted from the use of dynamite.

The difference between the cost of dry and subaqueous rock excavation is mainly in the cost of reducing the rock. This can be done at much less cost where the rock may be seen, so that experienced men can properly distribute the holes and the dynamite to accomplish the desired result.

Excavation. — Three traction steam shovels were used and the area was divided into three nearly equal parts, one for each shovel. The operators of the shovels became very skillful in handling their machines, and many large pieces of rock were removed quickly and without damage. All material was loaded into skips of about 3 cu. yd. capacity. Following the steam shovels, a gang of laborers cleared the bottom of all loose rock, loading it into the skips by hand labor. The loaded skips from the steam shovel and labor gang were carried to the spoil bank by the cableway and there dumped. After the removal of all broken rock, the elevations of the highest points of the bottom were obtained by the use of a surveyor's level as a means of determining that the required depth had been secured. Where necessary, high points were reduced by drilling and blasting and by hired labor. Thus, as the work advanced, it was left completed. The average daily rate of removing the material per steam shovel per day of eight hours, was 424 cu. yd.

Conveying. — Three cableways were used, one with each of the steam shovels, to carry the excavated material to the spoil bank. These cableways were of 726 ft. span, and they were supported by two towers each about 100 ft. high. Each set of cableways consisted of five cables: one to support the entire load, one to hoist, one to haul, one to dump, and one to support and distribute carriers to prevent entanglement of cables. The engine for operating the cableway was housed at the base of one of the towers. All signals to the engineer were communicated by the use of electric bells operated by a bell boy stationed where he could watch the work and receive his signals from the foreman. The process of dumping the loaded skip was as follows: The hoisting cable was lowered to the skip and when attached the load was raised to the required height, then hauled to the spoil bank, where it was dumped by the engineer throwing the dump line upon a larger drum causing it to travel faster than the hauling line, and thus dump the skip. The empty skip was then returned to the steam shovel by the reverse process. The signal for each of these operations was communicated to the engineer by the bell boy. This method of aërial dumping is the design of Mr. C. H. Locher, and it has greatly reduced the cost of disposing of material by cableways. As the excavation progressed, the towers were moved forward on tracks and kept abreast of the work.

Pumping. — The main pumping plant consisted of one 18-in. and two 12-in. pumps, all operated by steam. Also, there

were several smaller pumps which were moved where needed on the work; these smaller pumps were usually operated by compressed air. Except after heavy rains, a portion of the pumping plant was usually idle for a part of every day. The area first unwatered was 2 800 ft. long with an average width of about 1 500 ft. Within this area the average depth of water was about 6 ft., or the quantity of water was nearly 200 000 000 gal. This area was unwatered in about twenty-five days.

[NOTE. — Discussion of this paper is invited, to be received by Fred Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1911, for publication in a subsequent number of the JOURNAL.]

WATER RESOURCES INVESTIGATION IN MINNESOTA.

By Robert Follansbee, Member of the Civil Engineers' Society of St. Paul.

[Read before the Society, March 13, 1911.]

Introduction.

Before taking up in detail the work of investigating the water resources of Minnesota, I desire to outline briefly the history of this branch of the United States Geological Survey's work, in order to give a better understanding of its present status.

In 1888 Congress made an appropriation for gaging the streams in the western states, in connection with preliminary irrigation investigations. The limited funds available and the large area to be covered made it necessary to work out methods for carrying on the work that would give a degree of accuracy comparable with the main use of the records, — namely, to predict the future flow of the rivers. These methods were first developed by Mr. F. H. Newell, the director of the United States Reclamation Service, who was at that time the chief hydrographer of the United States Geological Survey.

A few years later there was a demand for similar data in the eastern part of the country, — except that there the use of the data were in the interest of power development, navigation, flood prevention, sewage disposal, municipal water supply, etc., instead of irrigation.

Congress gradually increased the appropriations sufficiently to allow the work to cover practically all sections of the country. At the present time the United States is divided into ten districts, and these districts are maintaining records of daily discharge at some 850 points on the rivers of the country. In addition to this, many rivers have been surveyed and much information collected regarding developments of water power, and kindred subjects.

It has always been the policy of the Geological Survey to coöperate with the states wherever state funds are available. When coöperation is effected, the work is carried on by the Geological Survey according to its standard methods, the state usually indicating at what points it wishes the investigations made. The pursuance of this policy of coöperation has been to

advance the investigations in those states which have contributed to the work much farther than they would otherwise be if dependent solely upon the Federal funds.

Lines of Investigation.

During the two years that the work has been carried on in Minnesota it has been divided into three parts, which have been carried on almost simultaneously: (1) The records of daily flow of the principal rivers. (2) The surveys of various rivers to show the water-power possibilities, carrying capacity for flood prevention, outlets for drainage systems, etc. (3) A census of the developed water powers within the state. Each of these lines of investigation will be taken up in some detail.

Records of Daily Flow.

As records of stream flow to be of value in predicting future conditions must extend over a period of years, on account of the variable flow from year to year, this branch of the work was taken up first by the establishment of 45 gaging stations on the more important rivers.

There are three methods of measuring the flow of rivers, — (*a*) by measuring the slope and cross section and using the Chezy formula with coefficients determined by Kutter; (*b*) by means of a weir; and (*c*) by direct measurement of the area of cross section and velocity, the latter by means of floats or current meter. The slope method introduces so much uncertainty that its results cannot be considered better than approximate, and therefore this method is seldom used. If it were possible to erect a standard weir this would be the most satisfactory method, but its cost is prohibitory in most cases and the existing dams in the state are not suitable to rate as weirs, on account of irregularities in the spillway section, various diversions of water around the spillway, leakage, intermittent use of flashboards, etc. Thus the weir method is not generally applicable. Practically all the stations are of the direct measurement type, with the current meter used almost exclusively.

The equipment essential for the maintenance of a current meter to measure the flow of the river is a structure (either bridge, boat or car and cable) from which measurements can be made (except in the case of very shallow streams, which can be waded) and a permanent gage to record the various stages of the river.

Current Meter. — After experimenting with many different

types of current meters, an instrument was devised that combined certain ideas of the large Price and the Price acoustic meters. This meter is known as the "small Price meter," and is used almost exclusively by the Geological Survey. It consists essentially of a yoke, which carries a set of six conical cups fastened together and set on a vertical shaft, causing the cups to revolve in a horizontal plane by the action of the river current striking them. To insure the cups being headed squarely against the current, the yoke has a large vane or tail attached to it. The vertical shaft terminates at the lower end in a conical cavity in which rests the cone-bearing on which the cup shaft turns. The upper end of the vertical shaft has a make-and-break contact spring. To the meter are suspended by a hanger sufficient lead torpedo weights to keep it in the proper place in the water. The meter is suspended by a cable composed of two insulated wires, one of the latter being attached to the make-and-break device in the head and the other being fastened directly to the hanger. The upper end of the cable is attached to a telephone receiver which is in the circuit with a small dry battery. Each complete revolution of the cups closes and opens the electric circuit, which is denoted by a sharp click from the telephone receiver. In practice, this receiver is usually fastened to the hydrographer making the measurement.

Before using, each meter is rated by drawing it through still water at varying speeds, and noting the distance passed over, the number of revolutions of the cups, and the time in seconds. From these data a rating table is constructed which gives, for any number of revolutions within a given time, the corresponding velocity in feet per second. Comparisons of ratings for meters of the same type and make show a very close agreement, the rating for any one meter rarely exceeding 1 per cent. of the mean rating. Subsequent ratings of the same meter show that the original rating holds as long as the instrument is in good repair and adjustment.

Methods of Measurement.—Usually a measurement is made from a highway bridge if the section is suitable. If there are many piers in the river, the section will not be suitable, owing to their disturbing influence. But if the piers are few and spaced quite far apart, their influence toward error will frequently be less than that of a measurement made from a boat, on account of the slight upward and downward motion of the boat, affecting the meter results. At the great majority of bridge stations there are not more than one or two piers in the section.

The vertical cross section of the river at the measuring

station must be normal to the direction of flow or, if it is not, a correction to the recorded velocity must be made. This is done by multiplying the recorded velocity by the cosine of the angle which a line normal to the cross section makes with a line parallel to the current. Points of measurement are laid off along the bridge, usually from 5 to 10 ft. apart (depending upon the width of the stream) where the flow is fairly uniform, and at additional points where the velocity changes suddenly or where there are sudden changes in depth, or where piers occur. In the latter case an observation is taken at each edge of the pier and at the points where the influence of the pier upon the normal flow ceases.

At each point of measurement the depth of the river is obtained by letting the meter down until it rests on the bottom, taking care that the meter is not carried downstream by the current. Then it is raised until the bottom of the weight just touches the water surface. The distance passed over by a given point on the cable indicates the sounding at that point. The meter is then lowered until the center of the cups is 0.2 of the depth below the water surface. It is held in this position while the number of revolutions in a period ranging from 40 to 60 seconds is noted. A check observation is made, and then the meter is lowered until the center of the cups is at a distance of 0.8 of the depth below the water surface, and a second observation made. The corresponding velocities are later obtained from the rating table for that meter.

The mean of the velocities at 0.2 and 0.8 of the depth is very nearly the mean velocity in the vertical plane at the point of measurement. This is substantiated both by theory and experiment. On the assumption that the vertical velocity curve is a parabola having a horizontal axis, the mean of the velocities at 0.22 and 0.79 of the depth will give very closely the mean velocity for the curve. Vertical velocity curves have been made under a wide range of conditions, by holding the meter at a number of points in the vertical plane and then plotting the results with depths below the water surface as ordinates and velocity in feet per second as abscissæ. Through these points the true vertical velocity curve is drawn. From this curve the mean velocity is obtained, which is compared with the mean of the velocities at 0.2 and 0.8 depth. Many hundred such vertical velocity curves have been made by the Geological Survey and the coefficient determined for reducing the mean of the 0.2 and 0.8 depth to the true mean. In all cases where the conditions of flow are normal the coefficient has been found to be very nearly

unity, which denotes that the mean of the velocities at these two points represents the mean velocity for the curve.

The following table shows the results of such determinations made in Minnesota.

COEFFICIENTS FOR REDUCING THE MEAN OF THE 0.2 AND 0.8 DEPTH VELOCITIES TO THE MEAN VELOCITY IN THE VERTICAL SECTION.

Station.	Depth. Feet.	Mean Velocity. Ft. per Sec.	Mean of 0.2 and 0.8. Ft. per Sec.	Coefficient.
Cannon at Welch	9.0	4.36	4.30	1.014
" " "	9.0	3.53	3.54	0.997
" " "	7.8	2.78	2.77	1.004
Cedar near Austin	1.4	2.465	2.455	1.005
Crow Wing at Pillager	4.4	2.01	2.02	0.995
" " " "	5.6	1.75	1.77	0.989
Des Moines at Jackson	2.6	1.64	1.64	1.000
Little Fork at Little Fork	4.8	2.43	2.44	0.996
" " " " "	4.4	2.01	2.01	1.000
" " " " "	3.4	1.88	1.88	1.000
" " " " "	3.1	1.94	1.98	0.980
" " " " "	3.0	1.90	1.90	1.000
Minnesota at Montevideo	3.3	2.14	2.14	1.000
" " "	2.9	2.02	2.06	0.980
" " "	3.0	1.51	1.54	0.980
Mississippi at Anoka	6.0	2.34	2.34	1.000
" " "	6.0	2.52	2.51	0.996
" " "	7.2	2.54	2.54	1.000
Mississippi at Fort Ripley	4.3	2.30	2.33	0.988
" " " "	5.5	3.20	3.20	1.000
" " " "	6.3	2.87	2.90	0.990
" " " "	7.2	2.77	2.78	0.998
" " " "	7.6	3.40	3.37	1.010
" " " "	7.6	2.90	2.98	0.973
Redwood near Redwood Falls	5.8	2.64	2.59	1.020
Root near Houston	3.6	1 28	1.32	0.970
" " "	7.0	1.46	1.46	1.000
Rum at Cambridge	5.9	1.92	1.91	1.010
" " "	5.2	2.20	2.18	1.010
" " "	4.0	2.00	1.95	1.025
Snake at Mora	3.2	1.50	1.53	0.980
Whiteface near Meadowlands	6.4	1.02	1.05	0.973
" " "	6.5	1.00	0.91	1.100
" " "	6.6	0.85	0.85	1.000
" " "	6.0	0.71	0.73	0.973
" " "	5.8	0.75	0.76	0.987
" " "	5.8	0.68	0.70	0.970
Zumbro at Zumbro Falls	1.35	1.84	1.80	1.022
" " " "	2.6	1.73	1.68	1.030

In extreme flood conditions it is not always feasible to hold the meter at the 0.8 depth owing to the swiftness of the current bowing the cable which suspends the meter. This bowing effect on the cable raises the meter somewhat, which is still further raised by being carried downstream by the force of the river in flood. Thus the exact vertical position of the meter in the water is uncertain. Under these circumstances it is customary to hold the center of the cups one foot below the water surface and apply a coefficient ranging from 0.85 to 0.92 to reduce the velocity obtained to the mean velocity.

Soundings and velocity observations are made at each point laid off across the river, which completes the field work of the discharge measurement, with the exception of reading the gage at the beginning and ending of the measurement.

In computing the measurement, the cross section of the river at the measuring station is considered to be divided into vertical strips, — each bounded by the points at which the soundings and velocities were observed. The area of each strip is obtained by multiplying the mean of the two soundings bounding it by the distance between them. This area is then multiplied by the mean of the mean vertical velocities at the points of the soundings. This gives the discharge through the strip in cubic feet per second (second-feet). A summation of the discharge through each vertical strip in the cross section gives the total discharge of the river at the time of measurement. If piers or other obstructions occur in the measuring section, the portion of the cross section thus obstructed is considered to have no discharge.

Accuracy of Meter Measurements.—To ascertain the probable accuracy of discharge measurements made by the current meter, comparisons have been made with the results obtained by sharp crested weirs. Under favorable conditions the meter measurement will differ not more than 2 per cent. from the weir measurement. A meter measurement can be duplicated under the same conditions within one per cent. of the first value. Of course the velocity at any one point cannot be duplicated that closely, owing to the pulsating movement found in the flow of rivers, nor can the discharge through each vertical strip be duplicated so closely; but the discrepancies are so largely compensating that the greater amount of the partial discrepancies is eliminated. In general, it is considered that all meter measurements made under favorable circumstances give results well within five per cent. of the true discharge.

When no bridge is available, measurements are made either from a car and cable or from a boat fastened to a cable stretched at right angles to the current. If the water surface is rough, a measurement made from a boat will give results somewhat large. This is due to the up-and-down movement giving a vertical velocity to the meter, which will cause the meter to register the resultant of the vertical movement of the meter and the horizontal movement of the current, instead of recording the horizontal velocity alone. Recent experiments have shown that, with a vertical movement of the meter of 1 ft. per second and an amplitude of 0.5 ft., the regular rating applies closely without correction to horizontal velocities above 2.4 ft. per second; for a vertical movement of 1 ft. per second and amplitude of 1 ft., the regular rating applies to horizontal velocities above 1.6 ft. per second; for a vertical movement of 0.5 ft. per second, and amplitude of 1 ft., the regular rating applies to horizontal velocities above 0.8 ft. per second. From the above it is seen that the magnitude of the effect of vertical movement of the meter during an observation varies inversely as the time of the oscillation, and inversely as its amplitude.

A better equipment than the boat and cable is the car and cable, which consists of a wooden car suspended over the river by means of a steel cable stretched across the river. By using this equipment the vertical motion due to the wave action against the boat is eliminated.

Gages.— In order to record the daily fluctuations of the river level which is necessary in computing the daily discharge, a gage is established at the measuring station. Two types of gage are used, — the staff gage and the boxed chain gage. Wherever it is possible to install it permanently, so that it will not be washed out by ice, floating débris, etc., a vertical staff gage is used as it requires very little attention to maintain it properly. Gage boards are made in 3-ft. lengths, and graduated to tenths of a foot. The value of each division is stenciled upon the scale to eliminate any errors in reading. A complete set reads from 0 to 15 ft.

When it is not feasible to put in a staff gage, a boxed chain gage is used, being placed usually on the bridge used in making the measurements. This gage consists of a composition copper chain, with a special weight about the size of a window weight attached to the lower end. The upper end of the chain has a marker which is used in connection with a scale placed horizontally on the bridge. The chain passes over a pulley rigidly fixed

on the bridge. To make an observation with this gage, the weight is let down until its lower edge just touches the water surface. The marker then indicates on the horizontal scale board the stage of the river referred to the proper gage datum. It will be seen at once that, in order to record the stage correctly, the length of chain must be correct, and the elevation of the pulley over which the chain runs must not change. To insure that the gage will read correctly, bench marks are established nearby, and the gage referred to them by level twice a year or oftener. Any slight errors are corrected by lengthening or shortening the chain the necessary amount. These errors, which are due to the chain stretching and to the pulley changing its elevation through changes in the bridge itself, rarely exceed 0.03 or 0.04 of a foot under ordinary conditions, and frequently the gage will not change at all during the year.

Having now considered the equipment used in maintaining a current meter station, the method of operating the station will be taken up.

Maintenance of Gaging Station.—The requirements of a satisfactory gaging station are,—(1) permanence of control at the section, so that at the same stage there will always be the same discharge; and (2) a good measuring section, in order that the current meter measurements may be accurate. A station having been selected which fulfills these requirements, a gage is installed and an observer engaged who lives nearby. At the majority of stations in Minnesota the gage is read twice each day and the mean of these readings taken as the mean stage for the day. On a few streams which are controlled either by power or logging dams the diurnal fluctuations of the water surface are so great that additional gage readings are taken, to approximate the true mean for the day. It is hoped that continuous records on a few streams whose flow is largely controlled will be obtained in the future by the use of automatic recording gages.

Discharge measurements are made at different stages of the river, such that a half dozen or more measurements will cover the range between high and low water. The results of these measurements are plotted on cross-section paper, with the mean gage heights at which the measurement was made as the ordinates and the discharge in cubic feet per second as the abscissæ. The measurements thus plotted define a smooth curve approaching the parabolic form, which is then drawn in. This curve is called the rating curve for the station, and from it a rating table is prepared,

which gives the corresponding discharge for any observed gage height. By combining the mean daily gage heights furnished by the local observer with the rating table, the daily discharge is computed.

Once the station is completely rated, — that is, has its rating curve well defined for all stages, — it is visited less frequently by the hydrographer, only sufficient measurements being made to see that the conditions of flow do not change, as any change would effect a change in the rating curve. If changes in the conditions of flow are found, it is necessary to make sufficient measurements to define the new curve. Even those stations where conditions are absolutely permanent are visited once or twice a year to check the gage with the bench marks and keep the equipment in shape.

The discharge data for the various gaging stations are published each year in the Water Supply Papers of the United States Geological Survey.

River Surveys.

The second line of investigation taken up was the survey of the various rivers for the general study of water power development, drainage, and flood prevention. It was not the intention to make final detailed surveys, but to obtain such information as would indicate their most prominent features, leaving detailed surveys to be made by those interested in the various projects.

Sufficient data were secured to determine the water surface of the rivers at medium stage, and to map the shore lines, adjacent topography, and the more important artificial features. This information has been plotted on the published sheets to a scale of either 1 000 or 2 000 ft. to the inch.

Method of Procedure.—The method used is that of the transit and stadia, carrying levels with the transit, making a magnetic traverse, and sketching shore topography.

A party consists of a topographer, transitman, two rodmen and teamster. The topographer, who is chief of party, keeps the transit notes and makes the topographic sketches, using a small field drawing board, and plotting the traverse shots as made. These sketches are invaluable when the final map is made in the office, and are very much more satisfactory than fragmentary sketches made in the transit notes, as they are plotted to scale (usually 1 in. = 1 000 ft.). The transitman,

as his name implies, runs the transit and directs the rodmen in giving the proper side and main shots. The transit is used not only to carry the traverse but also to carry the levels, which is done by using the transit as a level. Main traverse elevations are never obtained by vertical angles.

In order to illustrate the method of procedure, let it be assumed that the transitman has just reached a station. (As azimuth is carried by the magnetic needle it is only necessary to occupy every other station.)

The transitman, having set up his instrument, backsights on the preceding station, which was the forward station at the last set up, and, by reading stadia distances and magnetic bearing, locates his present position in the traverse. He then levels the telescope and reads the intersection of the middle wire on the rear stadia rod which gives the present H.I. He also reads the upper cross hair, and then the entire stadia interval (telescope remaining level). In this way he has a check not only on the distances, but also on the level reading, because if either is in error, the half interval consisting of the level reading and the upper cross-hair reading will not be consistent with the entire stadia interval, and in that case the observation is repeated until there is agreement. This check is of especial importance because, owing to the fact that only every alternate station is occupied by the instrument, there is only one stadia determination of the distance between stations. Both ends of the needle are read as a check on bearing, and in addition frequent section corners are tied in, as Minnesota is one of the states that has been surveyed by the United States Land Office. The rear rodman, having given the above described rear shot, moves forward, giving such side shots as are necessary to give the topography adjacent to the river banks and as far back as the bluff line where this is within a few hundred feet of the river. It must be borne in mind that it is not the function of these surveys to show the topographic features in elaborate detail, but only to show them in a general way and thus indicate the most feasible reservoir and dam sites, which it is expected will be surveyed in detail by those interested. In general, sufficient side shots are taken to sketch in the 5-ft. contours. The rear rodman having given the necessary side shots, which are augmented by hand level and pacing by the topographer in the vicinity of the station occupied, proceeds to a point on the river bank from 1 500 ft. to 2 000 ft. beyond the front rodman, so that when the transitman moves up he will occupy a position midway between the two, thus giv-

ing a back shot and front shot of from 750 ft. to 1 000 ft. each. Of course if the river is very winding it is not possible to take shots as long as this, as the rodman will not be visible.

During the open season the traverse points are chosen on the banks of the stream, the two rodmen keeping on one side and the topographer and transitman on the other. In this way every odd numbered station (transit station) is on one side of the river and every even numbered station (not occupied by transit) on the other side. A canoe is taken along for use in getting across the river whenever necessary.

During the winter season, however, the party walks along the channel of the river, and as the ice is usually from 1 to 2 ft. thick, the stations are taken directly on it. In both cases the elevation of the water surface is taken at the head and foot of all rapids, dams, etc., and at least every half mile in smooth stretches. These water surface elevations are the most important thing in the survey, as from them the profile is made.

In order to determine the magnetic variation, observations on Polaris, or solar observations, are made every few miles, and whenever local attraction is suspected, every station is occupied by the transit and azimuth carried in the regular way, but up to the present time very little evidence of such attraction has been found.

The profile of the river to show the true conditions must be referred to a stage of the river which is constant throughout the length of the river. Accordingly, gages are set at different points from ten to twenty miles apart and daily readings taken during the survey. As it is only feasible to make river surveys during the late summer, fall and winter, when the river has a fairly steady flow, it is possible to determine a low-water stage at one gage where the gage readings are practically constant for a long enough time for water to traverse the entire length of the river, and during this time the corresponding readings on the various gages are noted. These simultaneous readings denote the same low-water stage at each gage which is taken as the reference plane. Whenever the gages indicate a different stage than that of the standard one, the water elevations for those days are corrected by the proper amount as indicated on the nearest gage. As there is no great variation in condition of flow of the rivers surveyed, the relation of flow to gage height is fairly constant between two adjacent gages and there is very little appreciable error in correcting water elevations according to the nearest gage, even though that may be five or ten miles distant.

Of course if surveys were made during the flood season this method might introduce considerable error.

Accuracy. The initial elevations for each river survey are taken from a bench mark of the Mississippi River Commission, United States Geological Survey, or sometimes from a railroad bench mark, and thus all elevations are referred to mean sea level. By utilizing the surveys of various federal and state organizations, it is possible to get occasional independent checks on the level line. The results of these checks show that while the accuracy is not equal to that of good wye level work, it is well within the limits required for a preliminary survey of this type.

The checks obtained on three of the surveys are given as an example of the accuracy obtained.

On the Red Lake River Survey it was possible to check on well-established bench marks of other surveys which showed the following error of closure.

Distance by Traverse in Miles.	Closure in Feet.	Bench Mark of
33	0.13	U. S. Geological Survey.
70	1.6	U. S. Engineer Corps.
15	0.14	U. S. Engineer Corps.
37	0.51	U. S. Engineer Corps.
50	1.17	U. S. Engineer Corps.

At the end of the Rum River Survey levels were run forming a complete circuit of 55 miles. The error of closure was 0.5 ft.

On the surveys of St. Louis and Cloquet rivers, a complete circuit was formed which consisted of 208 miles of transit levels, and 16 miles of wye levels. The error of closure in the circuit was 1.16 feet.

Cost per Mile of River Surveys.—During the period from September, 1909, to May, 1910, eight complete river surveys were made. The field cost per mile of these various surveys is remarkably uniform, indicating that it makes little difference whether the surveys are made under winter or summer conditions.

River.	Field Cost per Mile.
Cannon	$7.68
Cloquet	8.88
Crow Wing	7.83
Ottertail	(*a*) 10.95
Red Lake	7.79
Root	7.77
Rum	7.85
St. Louis	6.69

(*a*) High cost due to greater detail in topography.

CENSUS OF DEVELOPED WATER POWER.

The third line of investigation undertaken was a census of the developed water powers. In this work each plant was visited, and answers to the following questions secured from the owner or operator.

1. Name of stream on which power is located.
2. To what large river is the stream tributary?
3. Location of power in township, county; above or below what tributaries?
4. Name of mill or power station.
5. Name and address of owner, or operator.
6. Have any records of height of water been kept?
7. What discharge measurements have been made in this locality? By whom?
8. Installed horse-power; average horse-power actually developed.
9. Use to which power is applied.
10. Market price of power in this locality.
11. Method of supplying water to wheels (canal or flume, pipe line, etc.).
12. Operating capacity of canal or pipe line.
13. Pondage (approximate area, range of head, capacity, flashboards).
14. Total operating head forebay to tailrace.
15. Water wheels (kind, make, age, size, usual gate opening, rated power at usual gate and head).
16. Water wheel governors (automatic or otherwise, make).
17. Generators (make, kilowatts, voltage, phase, current, connection, remarks).
18. Transmission lines (location, length, voltage, size of wire, kind of poles, etc.).
19. Hours per day plant runs.
20. Auxiliary steam horse-power.
21. Portion of stream flow plant is entitled to.
22. What part of the year is water supply sufficient?
23. Additional remarks.

No tests were actually made, although the installed rating of the wheels was checked by the manufacturers' tables using the average head available. The average horse-power actually developed was taken directly from the statements of the operators. In some few instances this was checked by the known flow of the river.

Bibliography.

For the convenience of those who desire to go further into the subject of stream gaging as carried on by the United States Geological Survey, the following list of references is given.

"The Use and Care of the Current Meter." (Trans. Am. Soc. C. E., Vol. 65, p. 70.)

"Current Meter Ratings." (Trans. Am. Soc. C. E., Vol. 47, p. 202.)

"The Parabolic Method of Computing Stream Gagings." (*Eng. News*, February 9, 1905, p. 154.)

"Comparisons of Formulas for Computations of Stream Discharge." (*Eng. News*, June 25, 1908, p. 682.)

"Accuracy of Stream Measurements" (by current meter). (Water Supply Paper 95, U. S. Geological Survey.)

"A Comparison of Stream Discharges Indicated by Current Meter and by Weir Formulas, Yakima River, Washington." (*Eng. News*, April 28, 1910, p. 481.)

"Current Meter and Weir Discharge Comparisons." (Trans. Am. Soc. C. E., Vol. 47, p. 370.)

"River Discharge," by Hoyt & Grover (Wiley & Sons).

"Determination of Stream Flow during the Frozen Season." (Water Supply Paper 187, U. S. Geological Survey.)

"Records of Flow at Current Meter Gaging Stations, when the Streams are subject to Ice." (*Eng. News*, May 11, 1905, p. 491.)

"Determination of Stream Flow during the Frozen Season." (*Eng. News*, February 2, 1911, p. 124.)

"The Design of Cable Stations for River Measurements." (*Eng. News*, May 6, 1909, p. 483.)

"Length of Records Necessary for Determining Stream Flow." (*Eng. News*, April 23, 1908, p. 459.)

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1911, for publication in a subsequent number of the Journal.]

SUBAQUEOUS PHENOMENA AT THE MOUTH OF THE MISSISSIPPI RIVER.

By George W. Lawes, Member of the Louisiana Engineering Society.

[Read before the Society, September 9, 1907.]

For a period of twenty-three years, during which time I was connected with the Engineering Department of the South Pass Jetty Company and the United States Engineers at the mouth of the Mississippi River, I had an opportunity to observe the phenomena of which I propose to talk to-night. Owing to the limited time allowed me for the preparation of the subjects, I will treat them only in a very general way, leaving the details to be brought out in future discussion.

I have no doubt that many of the members have heard of mud lumps, sand waves and counter currents, without, perhaps, having come in actual contact with them. There is also a silty sediment, peculiar to the passes, during low river, of which I have never seen any account, except in government reports, which are usually not too generally read. Therefore I hope my description of these phenomena will be of some interest, and, as the cause of them has never, to my knowledge, been definitely determined, the interest of some of the members of inquiring turn may be whetted to investigation.

Mud Lumps.—This formation is peculiar to the mouth of the Mississippi, but whether so to other sediment-bearing streams I have never heard. They occur principally in the vicinity of the easterly outlets of the Mississippi, though they also occur at the other passes. They are composed of a stiff, tenacious blue clay, that can readily be molded into any desired shape when moist, and is susceptible of a very high polish when dry. They vary in size from a few feet to several acres in extent, one of them accommodating a family, and on which they raised excellent truck for market. Previous to becoming covered with vegetation, and seen from a distance, they present a unique appearance, taking on fantastic shapes which are silhouetted against the sky in inky blackness. On closer inspection they showed a rugged, seamed, gray surface, where affected by the sun's rays, but otherwise have the inky color of the clay of which they are composed. It is claimed that their formation is spontaneous, and that they rise precipitately out of the water and

are dangerous to craft on the site of their foundation, catching them unawares and lifting them as they rise. My idea is, though, that this is rather imaginative, as, in the several that came under my observation at the mouth of South Pass, the growth was gradual, as soundings over them evidenced; then again, the formation may have been going on during a period of spring tides, which, followed by an extraordinary low tide, caused the lumps to appear a foot or two above water, and, without consideration, the unthinking observer jumped to the conclusion that the action was spontaneous.

The cause of the formation of the lumps has been attributed by some to the weight of superimposed sediment, and by others to pressure from gas which underlies all this territory. The lumps forming beneath the water are, of course, not susceptible to investigation; but they form in the marshes contiguous to the passes, and in these there is found a central crater up through which the material oozes and builds up the lump.

I saw several mud lumps that had formed off the mouth of the jetties, but none ever formed near enough to have any effect on the channel, and so the bugaboo that was so confidently predicted would destroy the jetties never materialized.

Counter Currents.—This is a most interesting phenomenon and its action very peculiar. The current is produced by the tides during low river, at a time when there is no river current. At times its presence is manifested by a turbulence in a portion of the river, where every other portion is placid. A stretch of water extending from bank to bank will be affected by a ruffling of the surface into waves of considerable height, dashing and beating against each other in angry commotion. This turbulence will travel up or down stream according to the direction of the flow of the tide and at a speed dependent upon its force.

During the first years the jetties were in operation, the bulk of the vessels entering them were sailing craft. The effect this current had on a vessel being towed into the pass was remarkable. Moving along at a speed of from four to six miles an hour, vessel and towboat would suddenly come to a standstill and there remain for hours, notwithstanding the utmost effort and power of the towboat. Again I have seen vessels weigh anchor, and against the united effort of two towboats, remain steadfast at the point of anchorage for hours. Some change in the tide or other conditions would finally affect the current and its influence be lost and the vessels would proceed.

My idea of the cause of this effect of the current is that the

vessel, owing to her greater draft, was immersed in a body of salt water underlying the fresh water in which the towboat rested, and this salt water flowing along the bottom, owing to its weight, exerted a greater retarding influence on the vessel than could be overcome by the towboat, working in the lighter medium. The turbulent effect of the current mentioned above has been attributed to mediums of different density working in opposition.

Sand Waves.— During my connection with the United States Engineers, one of my duties was to take sediment samples twice a week from the pass about two miles above the jetty entrance. In this way the amount and character of the sediment transported could be closely observed. I found in these observations that, after a long period of low river, during the first rise in the river, the sediment was composed of light material, usually silt, very little sand being present. Later, this material would be replaced by almost pure sand of a very coarse grain. This sand being extremely heavy, the least impediment to the current would cause it to drop to the bottom, and in such quantities as to cause serious shoaling in the channel. These shoals would move down the pass in series, and hence the name " sand waves " was applied to them. The shoaling usually occurred in the wider portion of the pass, and would obstruct the channel for longer or shorter periods, depending on the stage of the river to which this character of sediment was peculiar. Dredging had but a temporary effect in reducing the shoals, as a channel dredged one evening would be obliterated by the following morning; and often the dredge would work all day and produce no deepening in the channel. When this character of sediment ceased to be found in the water, the sand waves disappeared and the channel would improve naturally.

Silt Sediment.— During low river and when the hydrometer showed a preponderance of salt water in the pass, a thick, slushy sediment would be obtained in the sediment samples. This sediment was usually found near the bottom of the pass, in midstream, although samples taken at one-half depth contained it to some extent. (Samples of sediment were taken 150 ft. from each bank and in midstream, at the surface, mid-depth and 3 ft. from the bottom.) Three feet from the bottom in midstream, when this sediment was obtained, it would be seven-eighths silt, composed of clay with scarcely a trace of sand in it.

When this sediment was found in the samples there was always an undercurrent of salt water moving upstream.

I observed that when the river got low enough to admit

salt water in sufficient quantities into the pass, this water seemed to have a disintegrating effect on the sediment deposited on the banks during high water. The sand being heavy would not be disturbed, but the lighter particles would be, and gradually carried out of position. My idea is that the whole bed of the pass was affected in similar manner by this action and the material would slide down into the channel, and, when a strong under current of salt water occurred, would be lifted and carried in suspension.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston by July 1, 1911, for publication in a subsequent number of the JOURNAL.]

THE FUTURE OF MECHANICAL ENGINEERING.

By George W. Dickie, Member Technical Society of the Pacific Coast.

[Read before the Society, March 31, 1911.]

Ever since man learned to use an instrument to assist him in his struggle with the forces of nature, some knowledge of the mechanical arts has been necessary, especially to those whose business in life was to furnish their fellow-men with such instruments as the advance of civilization demanded. All through the history of the human race we find a constant demand for more instruments, through which to win more battles in the material world. From those days in the dim past when man first learned that nature herself was but his instrument, and made his first infantile efforts to subdue her, fashioning weapons of stone or flint to protect himself against his enemies of the brute creation, we can trace his progress down through the centuries, as the stream of human experience widens and deepens, till we find him in this twentieth century of light and progress, wielding at will the phantom of steam and the lightnings of electricity, traversing earth and sea by a power which nature, unknown to him, had been laying up in deep rock-bound storehouses long ere man's naked foot first trod the earth he was destined to rule; and we can see how the increasing knowledge has been made permanent by the ability man has acquired of being able to record the facts and experiences of his little life in the imperishable symbols of languages which have floated ever forward with the rising tide of human progress.

My own special branch of mechanics, to which my life has been given, that of marine engineering, is just about one hundred years old. The allied art of shipbuilding, however, is one of the most ancient, although its present-day wonderful development dates from its union with the mechanical engineer, — a union that has produced astonishing results; and through mutual achievements these two arts have become so interwoven that no line can now separate them. How rapid, of late years, the progress in shipbuilding and marine engineering has been may be illustrated by the following incident. Fifteen years ago, at a banquet of naval architects and marine engineers in New York, I ventured the prediction that I should live to see steamships

one thousand feet in length and of fifty thousand h.p. in the Atlantic service. This was considered by the technical journals at the time as rather a wild prediction, yet to-day the 50 000 h.p. has been exceeded and the length very nearly reached. The development of the modern steamship to dimensions not supposed to be within the possibilities a few years ago, is not the most interesting part of this development, to the engineer. The changes that have taken place in the economic evolution of the steam engine itself, and the various types of internal combustion engines that are beginning to challenge even the ultimate supremacy of the steam engine itself, are subjects that are keeping the mechanical engineer busy thinking, in these days, as to what his work is to be in the future. It is only a few years since the possibilities of the steam turbine were forced on the attention of the marine engineer by the trials of the *Turbania*, with the many problems which that event set him to solving. The rapidity with which the steam turbine has reached a commanding place amongst prime movers is one of the wonders of present-day engineering. In steamship propulsion alone, there must be about 2 000 000 h.p. in use to-day. Yet the steam turbine is not final, even for the fast steamer, for which it is best adapted. The reciprocating engine still has many friends who are very busy just now in the search of new ways of adding to the efficiency of that grand old instrument of steam propulsion, and now it is claimed that the very best economical result requires that both types of the steam engine go into partnership to get all the useful work possible out of the steam. This is due to the fact, now well known, that the high pressure end of the reciprocating engine is more economical than the high pressure end of the turbine, and the low pressure end of the turbine is more economical that the low pressure end of the reciprocating engine, and how best to fit the high pressure end of the one to the low pressure end of the other is the present problem of the marine engineer.

The mechanical problems, in connection with electrical engineering, keep multiplying at such a rate that they now form a large group of special subjects that no one engineer can master, — and the future promises a vast increase that bewilders the imagination even of those most at home in this wide field of engineering. The transmission of power generated by the falling of water from the mountains has in recent years changed the whole subject of power distribution and given to the money centers of the world a new line of investment and opened up a vast field

of achievement to the mechanical, the civil and the electrical engineers. How far electrical transmission can be carried from cheap sources of power and compete with local installations of steam-generated electricity, is a problem that is not yet finally settled. Great strides have been made in the economy of transmission by the use of high-tension currents, but at the same time high pressures of steam and more economical machines for converting it into electric power, coupled with the timely appearance of oil fuel in this state, cannot fail to affect the problems of transmission. The future is big with unsolved problems in this line of engineering.

The engineer has always been a man of tools, and early in the history of what might be termed modern mechanical engineering the tools with which he operated received the undivided attention of the very best mechanical minds of the profession. Such men as Clement and Whitworth, of England, and Sellers and Bement, of this country, gave the engineers of their day the tools that made the remarkable progress of the past possible and left little or nothing to improve on as far as function and accuracy were involved; but there came a time when high-grade steel took the place of cast iron and high carbon forged steel took the place of hammered iron, and tools to cut these new materials, combined with modern ideas of speed and economy, had to be produced. The progress of the past ten or fifteen years in the cutting of metals is one of the romances of modern engineering.

The future of this important branch of the engineer's work is full of deep problems that need not only the changing of things but the changing of men also. The engineer is no longer satisfied with producing a machine that is almost intelligent in its functions, but he must also have the man who tends this machine function in all his joints and muscles with the same regard to economic motion as the tool he tends. Where this will ultimately lead us might be a speculation for some of the learned societies at present meeting in Berkeley. I am sometimes afraid of the result of the modern idea of considering the man at a machine as only an integral part of the machine he operates, — only that and nothing more, — but then I have reached the reflective period of life, and my reflections sometimes lose sight of the economics of production.

Mechanical engineering in the schools is one of the problems of the future. How this problem should be solved depends on what the term mechanical engineering includes and what the student desires to prepare for in life. There will always be room

in the profession of mechanical engineering for the man deeply learned in the science of engineering, whose business is to deal with the laws that govern bodies in motion and the underlying principles that govern the correct theories of constructive science, with all the problems involved in the conversion of heat into work; in fact, all that is comprehended in that part of engineering that deals with the principles and laws that control the forces of nature with which he has to deal. But for the man who takes the findings of the engineering schools on faith and, by experience and continued effort in putting these laws into practice, becomes a practical engineer, too much time might easily be wasted in the engineering college. There is evidence now of a coming cleavage between these necessary branches of engineering. As for the working mechanic whose highest ambition is to manage a shop before he gets too old, his education must come from the kind of shop he hopes some day to manage.

I look for a wonderful future for mechanical engineering on the farm. For the small farm there is going to come what might be called the "universal" farm motor car, that will cultivate either on hills or level fields, the farmer being comfortably seated during the operation; then, by disconnecting the cultivating instrument and adding a wagon body, it will become the general means of transportation for what the plowing has produced; and when the farmer has a little time to take his wife and children out, a comfortable carriage body will take the place of the wagon. During stormy days, when outside work cannot be carried on, the universal farm motor car can be run over transmitting gear and its power used in cutting wood, or driving the well pump to fill the tanks, or may be operating tools by which the farmer may add to his convenience or comfort as opportunity offers. I feel, as I think of the possibilities of convenient power on the farm, that the engineer is yet to redeem farm life and make it desirable even for the progressive young people of to-day.

The mechanical engineer is also taking hold of the home, and working out for the housekeeper the problems that have, to a certain extent, enslaved women during the past history of the world. We may yet have an electric or motor maid-of-all-work that can be housed in a kitchen cabinet and which will need only a simple diet of gasoline or a chance to suck an electric wire, and which, with that simple compensation, will do our housework efficiently and without any back talk, will bake and wash and sweep for us, warm us when we are cold and cool us when we are warm. In fact, the absolutely-to-be-relied-upon maid-of-all-work

is among the future triumphs of the mechanical engineer. Thus not only our material progress in the future may be said to be in the hands of the engineer, but our domestic felicity also.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1911, for publication in a subsequent number of the JOURNAL.]

WHAT THE SCIENTIFIC AND TECHNICAL BODIES SHOULD BE DOING FOR THE COMING EXPOSITION.

By George W. Dickie, Member Technical Society of the Pacific Coast.

[Read before the general meeting of the Association of Scientific Societies, held at the University of California, Berkeley, April 17, 1911.]

Closely allied to the problem of getting exhibitors to come to San Francisco and install there, in the buildings provided, exhibits worthy of the occasion which will be celebrated here in 1915, is that of enticing visitors from all parts of the world to come and see what has been installed here for their inspection and judgment.

Visitors attend expositions for one or both of two principal reasons,—to be amused; to be instructed. The latter desideratum is fulfilled, in a large measure, by the commercial part of the exposition.

To bring together those who are seeking for something to satisfy some material want and those who are producing the things designed to meet that want, is the problem to be solved by an exposition.

Within the scope of that part of an exposition which may be called instructive or useful, as opposed to the part given over to providing simple amusement, are two classes of exhibitors, who are usually called the "commercial" and the "non-commercial." The commercial exhibitor looks upon his exhibit as an investment out of which he hopes to gain some profit directly or indirectly to compensate for the trouble and expense of exhibiting his product. He is usually charged for the space he occupies and for all transportation, installation, insurance and care involved in protecting his exhibit.

The non-commercial exhibitor is on a different footing, in that he incurs practically no expense, as the management collects, transports, insures, installs, cares for and safely returns his exhibit without expense to him. This would appear at first sight to be an unfair distinction, but a little reflection will show that it cannot be avoided, for the reason that, whereas the commercial exhibitor wants to exhibit only if he can profit by so doing, the non-commercial exhibitor cannot expect to profit, but the exposition must have his exhibit in order to get the visitors by

whom the commercial exhibitor is to make the gains, without which he will not exhibit.

The effect of the non-commercial exhibits on an exposition is best seen in connection with the subject of art. Without a notable collection of the fine arts no exposition can be considered complete. Loans of art works are always urgently desired, and exhibits connected with education, science and the numerous branches of the liberal arts are a great attraction to a large number of people. Yet even the fine arts are, to a certain extent, invaded by the commercial exhibitor, for we may divide the exhibitors there into two broad groups, — the painters and sculptors who exhibit for sale or reputation and the collectors who part with their treasures for a time and incur the many risks of transportation and exhibition to help the cause of the exposition and maintain the art reputation of their country.

The art exhibit is therefore a burden on the finances of an exposition, as are all the objects loaned for enriching the display. These matters constitute an important part of the work of holding an exposition and need careful attention. It will be necessary for the national commissioners of foreign countries and the state commissioners of this country to exert all their powers of appeal and persuasion to secure a great display of fine arts works at our exposition, as the success of this part of it will insure the presence of a large number of the most desirable visitors, who would not come here even to see the most elaborate display of industrial art.

The great bulk of the exhibits, however, must consist of natural and industrial products, and one of the big problems will be to secure these from all countries and of kinds varied enough to cover the whole field of human endeavor.

It having been decreed that this exposition is to be held in San Francisco, the State Department of our government will notify all foreign governments of the fact. Expositions have been held so frequently of late years that some countries have found it necessary to maintain a standing commission to represent them. There is a department of expositions in the British Board of Trade for instance, which attends to British interests at home and foreign expositions.

Other countries, which have no permanent organization of this kind, will at once appoint commissioners to manage the government participation and will place at their disposal the amount of money appropriated for their display. Our own government will have to decide on the extent and character of

the national exhibit, and all the states will provide funds and appoint commissioners to uphold their credit. But all of this will not make an exposition unless some fifty thousand or more manufacturers and producers scattered all over the world can be induced to spend money and time in the display of their products and industry.

To get these producers and manufacturers to come here is the problem of problems to be solved by the Exposition Company. The success of the proposed international exposition will depend on its solution.

Last year there was a great international exposition in the city of Brussels, Belgium. The Belgian organization committee in charge of the material part of the exposition constructed for exposition purposes the following buildings:

Industrial halls, Brussels side	600 000 sq. ft. space.
Industrial halls, Ixells side	550 000 sq. ft. space.
Machinery halls	285 000 sq. ft. space.
Hall covering rolling stock	109 000 sq. ft. space.

I have made some figures as to the relative amounts of space occupied by the several nations in the machinery halls, the only place in which the United States was represented by exhibits to any extent. The respective areas were as follows:

Belgium	134 600 sq. ft.
Great Britain	68 000 sq. ft.
Holland	33 000 sq. ft.
France	20 800 sq. ft.
Italy	14 300 sq. ft.
United States	14 300 sq. ft.

Germany, it will be noted, is not in the above list, for the reason that she had a great building of her own in which were gathered all her exhibits. This building had a floor area of 240 000 sq. ft. Great Britain had also a building of her own, into which she assembled all her exhibits except machinery; this building had a floor area of 192 800 sq. ft.

From this it will be seen that this country did not make much of a showing at Brussels. We shall be likely to hear about this when we ask European manufacturers and producers to come all the way to San Francisco with the product of their industry, to show what they can do and compare their work with ours. That will not, however, keep the European exhibitor at home if he can be assured that a great multitude of the people

of whom he can expect to make customers will be in San Francisco in 1915.

With the exception of manufacturers of certain grades of textile goods, and those manufactures embraced in the general terms "liberal art," there will not be many who can expect to secure customers in the United States. However, as this will purport to be an international exposition, the foreign exhibitor will naturally expect to find prospective customers from all over the world gathered here. It is therefore of the utmost importance that the man from abroad interested in these manufactures be enticed to come here, whether he be a British subject from the mother country or her dependencies, or from Greenland's icy mountains or India's coral strands. Your exhibitor will want to be sure that you can bring this class of visitor here. He will want to know if any great representation of the technical men of the world will be here. He knows who is the power behind the purchaser, and will want to know what is being done to attract him.

The men who are at the head of all technical work going on throughout the world are usually men of great scientific attainments. They are constantly seeking for new ideas and inventions, and they are ever ready to meet with other technical men and discuss the problems common to their several specialties. To this end numerous influential societies of a technical nature have been formed in every part of the world for the purpose of promoting discussion on matters of scientific and technical interest. The leading spirits of these societies are the eminent experts and leading inventors of the day. These men are the exhibitor's special care; if they are to be present in numbers at our exhibition, the exhibitor will be there with his display to meet them.

The Exposition Company will have to secure the hearty coöperation of the technical and scientific societies of this country in an effort to bring congresses to the exposition in 1915, for the membership of these socities is largely made up of the men who are the power behind the customers whom the exhibitors from foreign countries are looking for.

If the manufacturer of machinery expects to meet a congress of mechanical engineers from all parts of the world, he will be here with examples of the best mechanical work he can produce.

If the great bridge-building concerns and the manufacturers of materials and appliances used in civil engineering expect to find a great gathering of the civil engineering institutes and societies from all countries in one congress at San Francisco, they

will be here with models and examples of what they have done and can do to facilitate the work of the civil engineer.

If the manufacturers of electrical appliances, now so numerous, from great generating sets to wireless telegraph instruments, can hope to find here a representative gathering of electrical engineers from all over the world, they will be here in such force that they will fill the Electricity Building with the wonders of modern electrical science.

If the builders of locomotives and cars and the vast equipments required by the transportation companies expect to meet here the technical railroad men who are responsible for the equipment and operation of the railroads of the world, they will be here filling the transportation building with the latest designs of engines, cars and the intricate transportation equipments necessary to show the state of this art to these men who need their help in operating the world's railroads.

If the shipbuilders and ship owners of the world expect to find here in congress all the naval architects and marine engineers from the leading maritime nations of the world, they will be here to meet them with displays of all kinds of ship equipment and models, filling their section of the Transportation Building with the most interesting of exhibits.

If the manufacturers of chemicals throughout the world expect to find a gathering here of the societies devoted to the study of chemical science, they will be here to meet them with exhibits of the newest discoveries in their lines and the latest means of applying them to the needs of man.

In like manner we might run on through all the things that the technical world is interested in. If the exhibitor feels that he will meet here the men and women interested in the things he is making, he cannot afford to stay away. The influence of the technical societies of this country must therefore be brought to bear upon kindred societies throughout the world, to bring together in San Francisco at this exposition thousands of representatives from these societies to hold congresses and discuss together the special topics in which they as technical men are interested.

That is the thing which will bring exhibitors and the right kind of people to see the work exhibited. It was that, more than anything else, which made possible 28 000 000 visitors to the World's Columbian Exposition at Chicago. This adjunct to the exposition was managed by an organization known as the World's Columbian Auxiliary, — I had the honor of serving with

this auxiliary on the Advisory Council of the International Engineering Congress. I shall never forget the day when the various divisions of this congress met in joint session at the Hall of Washington in the Memorial Art Palace, Chicago, Monday, July 31, 1893, at ten o'clock in the morning. Charles C. Bonney, president of the World's Congress Auxiliary of the World's Columbian Exposition, called this most remarkable congress of engineers from all parts of the world to order. My first impression on entering the hall at the opening session was that of astonishment at the sight of thousands of eminent men in one busy profession who had found or made time to come from all parts of the world to attend these meetings and gather instruction from the great display of engineering work brought together for their inspection. The spirit which permeated all the opening addresses given by eminent men representing the great engineering societies of the world showed that no one expected to be a teacher there, but that all expected to learn something from the experience of others in exchange for what they had to offer from their own. I was thankful to be a unit in such a gathering, and also to find that, although the people whom I represented were far removed from the great centers of engineering enterprise, our work was known and appreciated by the leading engineers, especially of Europe.

It is gatherings such as this which will bring exhibitors and visitors to our exposition, and the machinery for bringing them about should be set in motion without delay, now that San Francisco is to have the honor and responsibility of furnishing the material means of celebrating the completion of the greatest engineering work in the history of the world. The great bulk of foreign exhibitors will be influenced by the prospect of meeting here the men who control the great enterprises going on in the world at large, and the only way to get them here in sufficient numbers to attract the exhibitors is through the influence of their fellow workers in this country drawing them by the power of association and the attraction of meeting kindred spirits interested in the same problems and eager to get together and concentrate on their solution.

Such great gatherings of technical men would come in kindred groups, possibly one congress a week during the active months of the exposition. In many cases they would come on specially chartered steamers through the canal, which in itself would prove a great attraction, or across the great Pacific Ocean. To bring this to pass, some sort of a Panama-Pacific World's

Congress Auxiliary to the Panama Pacific Exposition should be formed at once by the company, as the time for such work is getting very short. There seems to be a general impression among the people here that the success of the exposition will depend largely on local patronage. Success, in the widest and most enduring sense, will depend in no wise on local patronage. The uplift that San Francisco and California need, and are sick to-day for want of, must come from without. Contact with the great outside world of thought and action is what we need and must have if we are to grow. The opportunity to get in touch with the outside world is now within our reach. Such an opportunity comes but once in the life of any city or state. The leaders in thought and work who can be brought here from all parts of the world in 1915 would not come and go without leaving their impress on the city and state. They would also receive impressions that would find expression in their own countries, resulting in added millions to the population of our state, resulting in bettered conditions, not only for those who come, but also in new opportunities and increased prosperity for those who are already here.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 1, 1911, for publication in a subsequent number of the JOURNAL.]

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVI. MAY, 1911. No. 5.

IMPORTANT CONSIDERATIONS IN THE DESIGN OF HYDRO-ELECTRIC PLANTS.

BY A. P. MERRILL, MEMBER OF THE UTAH SOCIETY OF ENGINEERS.

[Read before the Society, January 20, 1911.]

BY an examination of the population in a given community, the industrial pursuits of its people and their general habits, surroundings, etc., one can obtain an idea of the power consumption, besides an insight into the future possibilities of the market. Growth along industrial or manufacturing lines usually parallels increase in power consumption.

In the past, power consumption has increased more rapidly than the increase in population or industrial pursuits. This is by reason of the fact that our present methods of utilization of the wasted resources of nature are comparatively new. During the past twenty years the larger proportion of our development along these lines has been made. In the meantime, while we have been learning how to apply the principles of science for our physical and social betterment, there has been a gradual awakening of the people of the country to the value of their natural resources. During the past eight or nine years conservation has been a much discussed subject. We are, at the present time, directing our efforts toward the preservation of our coal, mineral, timber, land and other resources.

In the state of Utah there are at present about thirty-five hydro-electric plants in operation. The capacities of these vary from the small two or three hundred kilowatt plant to the eight or ten thousand kilowatt plant. It is estimated that the average

yearly output of all of these plants combined is 25 000 horse-power. If we assume that it requires 4 lb. of coal per horse-power hour for the generation of steam power, we should consume approximately 438 000 tons of coal per year over and above our present demand. Were it not for our water-power developments we should either be deprived of some of what we now term necessities of life or we should be using coal for the purpose of generating the power now used. Hence, if we believe in the conservation doctrines as advocated (and I believe most of us do accept them, in possibly a modified form), it becomes our duty to advocate the development of our water powers. Does it not seem, therefore, that true conservation should encourage the development of water-power rather than to place such limitations upon future developments that they become undesirable investments?

If the necessity of encouraging hydro-electric development is accepted as a part of our present conservation doctrines, it devolves upon the technical engineering profession to see that the public has the proper attitude toward them. The public should know that an hydro-electric development is not materially different from any other kind of industrial development, as, in other industrial pursuits there are fixed charges on the investment, depreciation, changing market conditions and other things which have to be provided for. The public should understand that the gross income of a water-power company is not net earnings. At the same time it should not be so oblivious of the importance of these holdings that it is indifferent about them. Most of us believe in some sort of regulation of public service corporations. We believe that there is a certain relation between the public and all industrial pursuits; that were it not for the public our various industries could not thrive, and, as a result, there are some obligations which any company owes to the public. At the same time, public sentiment should not be carried so far in the other extreme as to cause it to place extreme or unreasonable limitations on this class of investments.

A power company has changing and shifting markets in many cases; loads which in themselves reduce the average output of its stations; outlays of capital for the purpose of insuring the proper kind of service; these and many other conditions are ones that must be met in a commercial market. The public should understand this, and upon the engineering profession rests the responsibility of properly informing it about these matters.

It is not the object of this paper to discuss in detail these questions, but rather those questions which arise in connection with the investigation and design of a power station or power system.

No engineer properly serves his client if he devotes himself exclusively to the engineering problems of a proposed hydro-electric plant or system. Commercial considerations are as important, and in some cases more important than the strictly engineering problems. Of course bad engineering is suicidal to any development, but commercial considerations should govern the engineering. Some water-power companies have failed because of neglecting to consider properly the relation between these questions.

No development should be made without a thorough preliminary investigation of all phases of the questions which arise in connection with it. If a proposed plant is to be built by a power company which has had previous commercial experience, of course no effort will be spared to obtain full and complete information on all questions pertaining to it. If the engineer's client is merely a promoter, whose sole aim is to sell or transfer his holdings for given values, it is sometimes a difficult thing to induce him to go to the necessary expense to properly determine their value. In fact, it is sometimes to the interest of the promoter to know as little as possible about his holdings, because a full investigation may show them to be other than he wishes. In such cases the less known about the project the better will the promoter be able to succeed. However, whether the client is a promoter, bond holder or a person who actually expects to make an investment of his own, the preliminary work should be done carefully and thoroughly. In the preliminary investigation a thorough study of the following should be made: First, the market; second, the nature of the stream, extent of its watershed and record of its flow; third, the possible storage; fourth, the surveys; fifth, water rights and rights-of-way conditions; sixth, reports, estimates, etc. These subjects will be discussed in the order named.

Market. — If a prospective plant is to be built by a power company and fed into an existing system, the market conditions are undoubtedly known. The power company has investigated them thoroughly and possibly the plant is built to meet existing conditions. In that case the engineer has little or nothing to do with this question. However, if the proposed development is in a new territory or is one in which the market conditions

are not known, then the most careful study is necessary. It is a comparatively easy thing to mislead investors in hydro-electric developments on questions pertaining to market conditions. The average load to the total plant capacity and the possible methods of charging may give results so different from those originally expected that the investment may be disappointing.

If there is a thriving and energetic community, a power market can probably be developed, but this is sometimes a slow process. People are naturally conservative and slow in utilizing new methods, especially if the new method necessitates an additional outlay of capital by the consumer. In some cases it is desirable that effective work be done on market development even before active work is started on the water-power sites. The natural inclination is to leave this part of the work until after the plant is built. Market growth then seems to be very slow indeed, and there are instances of water-power companies failing before their plants have really had an opportunity to show what their earning capacity is.

Stream. — In making our study of the stream conditions we are considering one of the most important phases of the preliminary investigations. The proper solution of many of the problems arising in connection with the design of a plant depends as much on the variations in the flow of a stream as it does upon the quantity of water available at different times. In this inter-mountain country our streams are peculiar not only in the exceedingly wide difference between their maximum and minimum flow, but in also what might be termed their individual behavior. The following are some of the influences which affect stream flow, especially in this locality: The character of the watershed with respect to its vegetation or other surface conditions; the general dip of the underlying strata, which determines in many cases the extent of the watershed and the extent of the supply from springs or other subterranean sources; the length of the stream; the position of the watershed with reference to the path of the sun; general direction of the prevailing winds; and the depth of the canyon through which the stream flows. Special attention should be given to these questions, as well as the annual precipitation and area of the watershed.

Before leaving this subject, some attention should be given to the available water-flow records in this district. Stream gaging work in this state has been done primarily for irrigation

purposes. Most of the measurements have been taken at the mouth of the canyon or at a point immediately above the canal system. This being the case, our available stream-flow records have only a comparative value for power purposes. As a general rule, our canyon streams are below what the geologist would call the water level. We should naturally expect, therefore, that each portion of the watershed has its own influence on the stream flow. However, the assumption is often made by different people or promoters that there is no increase in the flow of a given stream between the point where it might be measured and the point of diversion, which may be several miles further upstream.

No doubt many of us have had experience with people who happened to be promoting power propositions, and these people have with full confidence submitted records of stream flow in connection with their claims. A little inquiry will frequently show that these were taken far from the point of the proposed diversion. On two different occasions recently the speaker had occasion to measure streams at the proposed intakes of sites held by promoters, and he found the flow at those points to be less than one half the quantity which the promoter claimed was available. In each case, the promoter had gone to some expense to obtain his records, and he was submitting them in good faith.

If there is one thing that the speaker wishes to especially emphasize this evening, it is the necessity in all cases of having accurate and reliable measurements very near the point of diversion of a stream. He does not wish to be understood as maintaining that our available records of stream flow obtained in connection with irrigation work are of no value for power purposes. He does consider that they are exceedingly valuable for comparative purposes, but for comparative purposes only. If measurements have been made upon a stream at the mouth of the canyon, and these have extended over a period of years so that an accurate hydrograph can be obtained for the stream at that point, then a relation might easily be established between the flow at the point of measurement and the flow at the point of diversion. In that case, one year's records on a stream at the intake may make the other measurements nearly as valuable as if they had been taken at the proposed diversion.

Storage. — The value of a water-power development is very much enhanced if there are storage sites available. If there are relatively large storage sites it is quite possible that the flood waters may be stored and the minimum output of the

plant very materially increased. If such storage is not available it is sometimes possible that sufficient pondage may be obtained to permit the daily regulation of the stream. In this case an equalizing reservoir below the plant is usually necessary under our conditions, because of prior irrigation rights.

The importance of pondage becomes apparent if one computes the equivalent total kilowatt hours of the number of cubic feet of water flowing during the twenty-four hours, assuming no losses, and compares the result with the average number of kilowatt hours that we could obtain if no pondage were available. The average kilowatt output may be increased by pondage in many cases from forty to sixty per cent. It is seen, therefore, that the additional investment justified for pondage and equalizing reservoirs is, in most cases, a very considerable proportion of the total cost of the development.

In determining the reservoir possibilities, it should be remembered that all apparently promising basins are not adapted for reservoirs. It sometimes happens that a basin makes an excellent natural filter rather than a reservoir. It is as important to examine the nature of the soil at the bottom and sides of a proposed reservoir site as it is to make the surveys which determine its ultimate capacity.

Survey. — It is hardly necessary to say anything to a body of engineers about the value of surveys in connection with preliminary work of this kind. In spite of the importance of this work, no doubt many of us have had clients who were somewhat opposed to the idea of making the necessary outlay of money required to obtain the proper surveys. However, we are all aware that it is impossible to make an accurate determination of the value of the site or to make intelligent estimates on the cost of the total development unless this work has been performed. If the rights-of-way for the transmission lines or for the conduits appear in any way difficult to secure, the preliminary survey should be so made that the work of obtaining rights-of-way may be started much before the construction work begins. In many cases, this would prevent delays in construction and court proceedings after the work has been started.

Water Rights. — Our state laws are quite explicit on the method of obtaining the right to divert water for power or other purposes. An examination of the formal application blanks which are issued by the state engineer for these purposes will indicate fairly well what the necessary steps are. The chief thing, therefore, to determine in the field is whether the proposed

development will in any way interfere with existing rights. Power developments are often made in the canyons above the irrigation rights, and in these cases no conflict will arise. It is possible, however, on some of our streams, that irrigation rights may exist above a proposed power development. If this is the case, a careful determination of the nature of these rights should be made.

Reports, Estimates, etc. — In making a preliminary report the estimates should require very careful study. Unless one is backed by experience in similar work, it is often necessary that he makes at least tentative designs before making his preliminary estimates. If the engineer does not do this, he need not be disappointed if the construction costs differ widely from his preliminary estimates. It is not uncommon to hear engineers very severely criticised because of estimates they may have made. The speaker's experience has taught him that these errors are often due to the tendency of the engineer to figure too closely on his preliminary work. What the speaker means by this is that there is not sufficient margin allowed for the uncertainty of the case. A preliminary estimate if it errs at all should err on the safe side. This would frequently save our clients and bondsmen very serious trouble later.

The engineer's report should be conservative and should state the facts plainly. Facts do not often deceive and frequently a mere statement of these will determine the outcome of a proposed development. It is the speaker's opinion that the engineer should not permit his personal convictions to influence his report in any manner. It is far better to state the facts and conditions as they exist, and leave the client free to form his own convictions.

After the preliminary work, as outlined above, has been made, our clients should be able to draw their own conclusions as to whether or not the site is a good one. If it is good, it is one which is capable of producing an output, after all losses are deducted, which an available market can utilize at a price which will insure the necessary returns on the investment. This statement applies to a system of water-power plants as well as to an individual plant.

If our client, after an examination of the engineer's reports, decides that the investment is a desirable one, we are then ready to enter into those questions which arise in connection with the detail design.

Plant Capacity. — One of the first things to be decided in this connection is the number and size of units. To do this,

two sets of curves are necessary: those showing the probable daily load variation and a hydrograph of the stream showing the daily, monthly and yearly variations. The relative importance of these two sets of curves depends upon whether or not the proposed plant is to operate alone, in connection with other water-power plants, or in connection with a combined steam and water-power system.

As a general proposition, we may say that for the best results a unit should operate somewhere between three quarters and one and one quarter of its normal rating. These operating conditions are determined more by the water wheels than by the generators, as the efficiency curve for the water wheel is frequently considerably sharper than it is for the generator.

If the plant is to be used independently, its load factor will probably be comparatively low and the load curves alone determine the size of the units. The size of the units settled, the number of them will be determined by the amount of storage available or the value of the secondary power and what is considered necessary in the way of spare units. If there is no storage and the secondary power is of relatively small importance (as it is likely to be on our streams having relatively short periods of high water), it is quite probable that the ultimate plant capacity is determined by the provision to be made for spare units rather than provisions for secondary power. In other words, it is not always necessary that spare units be provided during periods of high water. However, if the secondary power is the thing that determines the ultimate plant capacity, it becomes a question between the earning capacity of the secondary power available and the additional investment required. The hydrograph then has considerable importance in determining the size of units.

If the proposed plant is to be used as an addition to an existing hydro-electric system, with no steam power, the same curves will be used in determining the unit size, but they will probably not have the same relative importance. The hydrograph of the stream will be more important, while the load curves will be less. A load curve will be drawn for the system as a whole, and not for the proposed plant alone. The considerations determining the maximum capacity of the plant will be the same as before, but the spare units will not have the same relative importance.

It frequently happens in a partially developed power system that an additional water-power plant is to be considered as

taking the place of a steam plant. It may be operated as such until the demands on the company require that the steam plant be also built, or until additional water-power developments are made. If there is sufficient pondage above the intake to enable the plant to use all the water on its load, let that load vary as it may, and if there is an equalizing reservoir below the plant, the new water-power plant could take the place of a steam plant very nicely. The generator in the new plant could be operated as a motor when the load begins to reach the limit of the other plants, and the governors in the new installation could be so adjusted that water would be automatically turned on to the wheels when necessary. If the new plant is to be considered the equivalent of a steam plant, the load curves again become very important in determining the size of units.

By far the easiest conditions to be met in the design of a new water-power plant are when the new development is an addition to a combined system of steam and water-power plants, and the new plant is to be operated at one hundred per cent. load factor. In this case the hydrograph alone will be used in determining the size of units, and pondage is of little or no value. The maximum output of the plant would be determined by the relation between the cost of what would otherwise be considered as secondary power and the cost of equivalent steam power. It is quite probable (for this locality especially) that the maximum capacity of the plant would be somewhat higher under these conditions than it would in the first case considered

Dam and Intake. — After determining [illegible] number of units, we are prepared to go into the details of [illegible], intake and the conduit. Under our conditions here, of relatively small volumes and high heads, the dam and intake are merely diverting works and they do not form, as they do in many places in the East, one wall of the power house. The speaker considers the following some of the requirements to be met in the design of diverting works for power purposes: First, they should be permanent in character and carried to a sufficient depth to prevent seepage under them; second, they should be so designed that flood waters can be easily handled; third, provision should be made for preventing floating débris from entering the conduit and to allow the settlement of small gravel or pebbles which may be carried by the stream during high water; fourth, provision should be made for the insertion of fish screens at the intake. Our state laws require this.

Conduit. — The speaker never discusses the question of

conduits unless he recalls the advice given him by the manager of one of the large power companies on the Pacific coast. This was as follows: "Eliminate all wood construction in your development; bury your conduit where possible; and tunnel a hill rather than go around it." We have heard of laws that are too stringent to be enforced, so it is probably not a misdemeanor to consider this advice too good to be followed. No doubt we would all like to build as this manager advises, but generally we have limitations placed upon us. Not being able to follow this advice rigidly we should make the nearest justifiable approach to it.

It is no doubt fortunate for many of our developments in this section that they are so located that an earthen conduit is impracticable. Were this not the case some of us might be foolish enough to adopt it.

So far as the speaker knows, closed reinforced concrete conduits have not been adopted in power development work in this state as yet. We shall probably get to it later when our power and market conditions become more stable. In most of the developments made here, so far, wood and steel have been used. In many cases the open flume has been adopted, while in other cases continuous stave pipe has been used. While the speaker has made comparative estimates for only a limited number of sizes of pipes and flumes, he believes that, assuming first-class construction in each case, the first cost for the pipe is somewhat higher than for the flume. At the same time he believes that the higher cost of the pipe is justified for the following reasons: First, it can be laid below the hydraulic grade, thus insuring saturation of the wood and, as a result, longer life to the conduit; second, the line can often be materially shortened by the use of inverted siphons under moderate heads, thereby often decreasing grading and other construction costs; third, the closed conduit practically eliminates ice problems after the water once enters it; fourth, closed conduits eliminate the necessity of spillways near the plant, which are, in many cases, expensive, and, quite frequently, troublesome; regulation of the stream flow can be accomplished at the plant; fifth, the closed conduit has a storage capacity which often permits the plant to handle peak loads of short duration which it would otherwise be unable to do; sixth, the effective head is materially increased during low water periods.

The speaker considers the last-named reason the most important of all, and in most cases it alone justifies the difference

in cost. In a recent installation where secondary power was not considered very valuable, the speaker permitted a total drop in head due to friction of approximately sixty-five feet, when the pipe was carrying its maximum flow. The same conduit would cause a friction loss of only twenty feet during periods of average minimum flow. In this particular instance the difference in friction losses between the maximum and minimum flow caused a very appreciable difference in the output of the plant during times of low water.

Penstocks. — The heads under which most of our plants in this section operate eliminate from consideration anything but steel for the penstock proper. Pipe made of sheet steel and riveted on both the horizontal and vertical joints is used for moderate heads, while lap-welded pipe is used for the higher heads. Very frequently there is a gradual reduction in the diameter of the pipe as it extends down the hill, the minimum diameter being determined largely by the maximum velocity of water allowable and the influence of the velocity of the water column on the regulation.

If the pipe is to be anchored so rigidly that movement will not be possible, the stresses due to expansion and contraction should be taken into consideration in determining metal thicknesses. It is not infrequent, however, that the profile of the line is such that some movement of the pipe is permitted without in any way injuring the penstock. There seems to be considerable difference of opinion about the desirability of providing expansion joints, some engineers preferring to increase the metal thickness sufficient to allow for increased stresses due to expansion or contraction.

Theoretically, if contraction and expansion stresses are to be eliminated, there should be an expansion joint immediately below each anchorage. There have been instances of quite serious trouble with penstock where no provision was made for temperature changes. The trouble occurs in the joints, the contraction of the line causing serious leaks at these points.

While the speaker does not advocate any one method of meeting the difficulties due to expansion and contraction, he considers it absolutely necessary to take the temperature stresses into consideration in the design of the line. They can be provided for in one of three ways; namely, by including these stresses when determining the proper metal thickness; by making provision for the changing lengths of the line, by either permitting motion as a whole, where conditions are favorable,

or by the use of expansion joints; and by burying the pipe so that temperature stresses are practically eliminated. Each method has its advocates, but, as a general rule, conditions should determine which method should be used.

It having been determined how the expansion and contraction shall be provided for and how much the static head should be increased by reason of water ram in the pipe line, the detail design of the penstock is not a difficult matter. The factor of safety, efficiency of joints, methods of calking joints, field erection methods, kinds of pipe coating, etc., are questions which the engineer settles by using his good judgment or by applying principles which his experience has demonstrated are correct.

Regulation. — Before deciding on the details of a station layout, it is necessary to work out the methods of speed regulation. Present commercial requirements are such that the allowable percentage of speed variation is very small indeed. It is absolutely necessary, therefore, that some automatic means of regulation be provided.

It has been advocated by some that it is not necessary to provide automatic regulation in each plant of a system of plants; that automatic regulation is necessary in one or two plants only, and that hand regulation is sufficient for the balance. It is assumed, of course, that the plants operate in parallel.

The speaker has reached the conclusion that some sort of automatic regulation should be provided in any case. We might conceive of some circumstance which might place the governing plant out of commission, and this would leave the system without speed regulation. Then, again, certain errors in switching are possible, or some internal or external condition might arise which would open some of the oil switches. In either case the results might be disastrous in a hand-regulated plant. We occasionally hear of catastrophes due to runaways. If conditions are such that it is desirable that all regulation be done at some individual plant, it is entirely feasible to set the governors in the remaining plants so that the ordinary load variation will not affect any but the governing plant. The governors of the other plants would then be required to operate only in extreme cases, but at the same time they would protect them from what otherwise might result in serious accidents.

Having decided that automatic speed regulation is necessary, the question to be determined is whether we will permit our governors to operate directly on the water column, thereby changing its velocity, or whether some indirect method will be

adopted whereby we might regulate without doing this, — the velocity changes being effected by hand regulation. If there is storage available, we are justified in permitting the governor to operate on the water column as it is important that no water be wasted. If there is no pondage or storage and we are compelled to allow the constant flow through our pipe lines anyway, by reason of prior rights on the stream, one of the indirect methods of governing should be adopted. If we decide to adopt the tangential wheel, we may govern without affecting the pipe line velocity by the use of the deflecting nozzle, the stream deflector or deflecting hoods, the synchronous by-pass, or the governor operated water rheostat. If we adopt the reaction turbine, we can govern by the synchronous by-pass or governor operated water rheostat. The methods indicated above have proved themselves satisfactory, with possibly rare exceptions, and the choice of the proper one will probably be determined by other considerations in the station layout.

There is one consideration which would tend to make the governor-operated water rheostat particularly desirable in the turbine installation where water saving is not feasible. It is quite important that the turbine be operated at about its normal load at all times, as the water on entering the veins of the runner should have the proper relative motion or direction with respect to them. If this condition does not exist, experience has demonstrated that the life of the runner is considerably shortened by reason of pitting and corrosion. The governor-operated water rheostat enables us to maintain the desired load at all times, besides insuring better voltage regulation.

As intimated above, the only justification for permitting a governor to operate directly on the water column in a manner other than on a synchronous by-pass is the value of the water saved. This method of regulation frequently introduces an element of danger to the penstock and pipe line, and it is likely to increase the installation cost very materially. It is sure to necessitate the building of a standpipe or its equivalent. Nevertheless, when we remember that our average plant output can be doubled in many cases by reason of available storage or pondage, we are entirely justified in permitting the increased cost referred to.

At the present stage of hydro-electric development, the difficulties encountered when we adopt that method of speed regulation which involves a change in the velocity of the water column arise by reason of the difference between the demand

made upon the plant and the effective work performed by the water during the governing period. This difference between the demand upon the unit and the effective work developed by the water is due to the following causes: First, sluggishness of the governor; second, sluggishness of the water column; and, third, inertia of the water column.

The successful water-wheel governors used to-day are those which are made operative by reason of a speed change, and after they are made operative a certain amount of time is required for the governor to make the change necessary. While these changes are taking place the work done by the water is either in excess of, or below, the load demand. The amount of this excess or deficiency depends upon the sensitiveness and time element of the governor.

As it requires time to transmit sound through the air, so it requires time to change the velocity of a water column. During the time required for this change, the work done by our plant continues to be in excess of, or below, the load demand.

For conditions as we usually find them in this section, and with a closed conduit between the plant and the intake, the largest excess or deficiency in output will probably be due to the energy required to accelerate or retard the velocity of the water in the pipe line. It is an easy matter to compute the kinetic energy stored in a moving water column with a given velocity, and by making the calculations for the velocities before and after load change we can readily determine what this excess or deficiency is.

In a recent work on "Water-Power Engineering," Daniel W. Mead outlined in his "Appendix B" a method whereby we can compute the power curve, for a given case, during what might be called the output changing period. It is beyond the scope of this paper to discuss in detail the mathematical questions arising in the solution referred to. It is proposed to discuss in a general way only the information acquired by this solution, and its practical bearing on hydro-electric installations. It is true that a complete solution of the problem requires some rather tedious mathematical processes, and the temptation is rather great at times to substitute "judgment" for accurate information. However, the solution of the problem is not so laborious that we are in any way justified in ignoring it. Hydro-electric engineering is based on scientific principles and these principles should be applied in our work.

After we have computed the data and plotted our power curves during load changes, the following facts become apparent:

If the load demand has suddenly increased, the governors, within a certain period of time depending on their sensitiveness, tend to open the gates. By reason of the causes above mentioned, instead of the power output of the unit increasing exactly with the gate movement (assuming that no special provision has been made for overcoming this effect) it first drops even below the output before the gates were opened. In a short time the output begins to increase and it continues to do so until it equals or exceeds the demand. The time required for the output to equal the demand depends upon the effective head, the length of the pipe line, the load change, etc.

If, on the other hand, our load demand suddenly decreases, the gates tend to close and, for the same causes, the output is in excess of the load demand, and a certain period of time will elapse before conditions again become normal.

The changes just mentioned are the ones that give rise to the " water rams " or " surges " that are so frequently discussed by engineers, or in the technical press, and which have resulted so seriously in a few instances.

If we have plotted our power curve as we should, it will be apparent that there must be a certain relation between the time required for the governor movement and the period of excess or deficiency. Unless the time element of the governor is properly adjusted, its tendency will be to follow the power curve too closely and instead of being an element of safety to our plant it may become an element of danger. The speaker thinks of governing in this connection as being the combined effect of the governor proper and any auxiliary devices that may act directly on the water column.

In the discussion so far, the speaker has assumed that the pipe has been entirely closed between the power house and the reservoir. The next problem will be to find some practical method of making our power curve conform more nearly to the demand curve. The water-wheel manufacturers are largely overcoming our difficulties so far as the excess energy is concerned. They are providing automatic by-passes which open as soon as the pressure rises a predetermined amount above normal, and the excess energy is thus wasted. The literature quite freely distributed by the manufacturers clearly outlines the various present methods of accomplishing these results.

The excess energy being provided for by the manufacturer, it remains for the engineer to find some practical means of supplying the deficient energy. The surge tank appears to be the most

practical remedy at the present time. This may be merely a pipe at the head of our penstock or a combined air chamber and compressed air tank under pressure near the power house. The methods of designing and proportioning surge tanks are discussed at length in Mr. Mead's work above referred to and in a paper on "The Surge Tank in Water Power Plants," by Mr. Raymond D. Johnson, in a paper presented at the Detroit meeting (June, 1908) of the American Society of Mechanical Engineers, besides other papers and discussions published by the technical press. It would be useless, therefore, to treat this subject in detail here.

There is one danger that arises in connection with the use of the surge tank in this and other localities. Our climates are such that, unless special provision is otherwise made, it is likely to freeze. The cost of preventing this, if the surge tank is constructed near the power house, is sometimes prohibitive. It is quite frequently possible to provide a simple standpipe up the mountain side at the head of the penstock, and this can generally be buried at a relatively small expense. If this is done, it is often possible to supply the deficiency arising by reason of the pipe line between the standpipe and water wheel, by a special fly-wheel, if the energy in the revolving parts of the generator is not sufficient. The smaller the percentage of speed change allowable, the larger the fly-wheel required.

Machinery. — After having proceeded thus far, we are ready to select our machinery. However, before discussing this question in detail, a few general remarks about the equipment might not be out of place.

Under no circumstances are we justified in purchasing anything but first-class equipment. The difference in output between a first-class unit and an inferior one would many times pay for the difference in costs of the two classes of equipment during its lifetime, to say nothing of the value of the greater reliability the better equipment insures. There are enough manufacturers making first-class machinery, both hydraulic and electrical, to enable one to obtain as much competition as necessary to insure him that his prices are right. While the speaker believes that competition is a very desirable thing, he thinks it should be conducted with proper limitations. It would be entirely unfair, for instance, to invite the manufacturer of high-grade machinery to compete in price with inferior articles. The same principles apply in the purchase of machinery that are applied in the purchase of clothing.

There is another matter which should concern us also. We ought to be sure that the business of the manufacturer is permanently established and that the equipment we purchase is standardized as far as its type will permit of standardization. If the kind of equipment does not permit of complete standardization (as is the case with our water wheels), we should be sure that the company is one which maintains complete records of all articles sold. While the hydraulic equipment is not always susceptible of complete standardization, it is quite possible to standardize certain general types and forms, and a given installation requires modifications in dimensions only.

The importance of these statements may not appeal to us until the time arrives when we are ready to replace parts of our equipment, and if we have erred in making our selection, we are likely to be informed that the desired parts are no longer available; that the records do not exist which show exactly what was furnished; or that the company has failed, — either case necessitating the purchase of an entirely new machine.

One of the first questions that arise in our minds when selecting machinery is: What type of water wheel shall be adopted?

Some time ago this question could be more easily answered than it can now. At one time we thought that we had reached the limit for the reaction turbine when we obtained an effective head of 200 ft. Of late years the Francis turbine has been successfully used on heads between 600 and 700 ft. Hence with an effective head between 200 and 700 ft., the engineer now has his choice between the reaction turbines and the tangential wheels. He will, therefore, investigate the claims presented by the manufacturer of both, and the type will be selected after giving due consideration to the relative costs, reliabilities, efficiencies, depreciation, operating conditions, etc.

The question of the overload capacity of the unit is one which should be given some thought. In deciding this question the curve drawn between efficiency and load, illustrated in Fig. 1, will have an important bearing. The form of the curve for any specific case can be very closely approximated by the manufacturer.

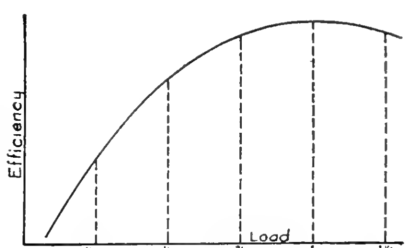


Fig. 1

Let us assume, in

order to bring out the desired point, that our station is to be a two-unit plant. Each unit, of course, will be so designed that its normal load will be at the point marked "1" in the diagram. The normal rating has been determined by our average water or load conditions, but, of course, our stream flow varies from the maximum flow, provided for in our designs, down to the extreme minimum. Let us assume, now, that we have 25 per cent. more water than is required to run one machine at its normal rating; and let us suppose also that the unit has no overload capacity. In order to utilize our additional water we could continue to operate the first unit at its normal load and the second one at one quarter of its rating, or, we could divide the load and operate both units at about $62\frac{1}{2}$ per cent. of their normal rating. In either case, it is not improbable that we should find that our 25 per cent. increase in water is of very little use to us. On the other hand, if our unit is designed with an overload capacity of 25 per cent. the form of the efficiency curve will no doubt be such that the output of our single unit is more than the output of the two units would be under the same conditions. Theoretically, the overload capacity of each unit should be such that it would have the same efficiency at its maximum load that each of the two machines would have if the load were divided between them.

The speaker does not advocate that the maximum capacity of the machines in a two-unit plant should be as high, in all cases, as this consideration would require, but after consultation with the maker about his limits, etc., we should make the nearest practicable approach to it.

The same principle applies in determining the overload capacity of the units where more of them are used, but, of course, the range of loads will not be so wide.

The speed of the unit will be determined after consultation with the manufacturers of both the hydraulic and electrical machinery. The one selected will probably be a compromise between the ones desired by the two companies. However, as the electrical companies now have standard speeds for water-wheel type of generators, covering a rather wide range, the hydraulic conditions have the greater influence in determining the proper one to adopt. This is more especially true with turbine installations. In tangential installations we have a little more liberty, as wheels can be designed for given installations which appear to have comparatively small differences in efficiencies for the different speeds selected. In these installa-

tions it has been the custom of the speaker to determine a desired relation beween the floor level and the shaft line, the generator also being taken into consideration in establishing this, and then to select that speed which will give the tangential wheel such a diameter that the nozzle levels can be maintained at a desired point. Sometimes it is desirable that out baffle plates be placed in the concrete below the level of the machines, and, generally, this necessitates a wheel of rather large diameter. The speaker has also found, however, that the larger wheel diameter gives a better balance between the tangential wheel and the generator. These are largely matters of personal preference, however, and the engineer will use his judgment in deciding them.

Unless our plant is to be designed to meet some special condition (and this is not often the case), a generator having a frequency of sixty cycles per second will no doubt be selected. This seems to be the frequency which will most nearly meet the average market conditions at the present time. The voltage of the generator will be determined largely by the conditions to be met. If the plant happens to be an isolated one, the engineer is sometimes justified in adopting generators having the voltage he desires to adopt for his distributing system. More frequently, however, it is desirable to install transformers for other reasons, and when this is the case, a machine having a medium voltage of possibly 2 300 or 4 000 volts will probably be used. Machines designed for the voltage and frequency mentioned have become thoroughly standardized, and we may know within very narrow limits just what the regulation, temperature rise, and insulation of the generator will be, beside a fair knowledge of the degree of reliability we may expect.

At the present time we have a choice of a number of different methods of exciting our generators, or, more properly, of driving the exciters. The exciter may be mounted either on the shaft of the generator between bearings, or, it may be mounted on an extension of the generator shaft and immediately outside of the bearing. It may also be belt driven from the generator shaft, or it may have an independent drive consisting of a water wheel alone, or of a combined water wheel and induction motor drive. Very frequently the speed adopted for the unit determines whether direct mounting on the shaft is desirable. Probably the method most commonly adopted for driving an exciter in a small or medium-sized plant is by a belt from the generator shaft. When a Tirrill regulator is used, which is usually the case in our modern and well-designed plants, the belt-driven exciter

serves its purpose very well indeed, provided the exciter is to be used for excitation purposes only. Experience has demonstrated that it is not often desirable to drive an exciter by an independent water wheel alone. Before the Tirrill regulator became so commonly used, it was thought by many that separately driven exciters overcame many of the difficulties that arose in connection with voltage regulation. However, at present, we are justified in saying that when the Tirrill regulator is used, the belt-driven machines are more satisfactory for excitation purposes than water-wheel-driven units. If we drive the exciter by an independent water wheel alone, we have additional regulation troubles, and these are not so easily handled as it might appear at first sight. The exciter units in our medium-sized plants are comparatively small, and it frequently happens that small gravel or floating material, which do not interfere materially with the larger unit, very materially interfere with the operation of the exciter unit. This statement does not apply, however, if we have coupled to our exciter shaft an induction motor in addition to the water wheel. If at times the station auxiliaries require a comparatively large direct current for their operation, a combination motor and water-wheel-driven exciter is very desirable. The motor driving the exciter eliminates most of the hydraulic difficulties that arise in connection with the water wheels, and we are also enabled to use exciters for purposes other than excitation without seriously affecting our regulation. It is seen, therefore, that the engineer will be required to use his judgment in the selection of the proper method of driving his exciters as well as in many of the other problems that arise.

The speaker does not intend to discuss, in detail, switches or switchboard design. A switchboard is used for the purpose of controlling and measuring the output of our stations, and it is important that we should provide adequate means of doing this. Enough instruments should be provided to enable us to determine our operating conditions accurately at all times. After specifying the requirements of each individual case, the details of the switchboard can well be left in the hands of the manufacturer, or to the switchboard specialist.

At the present time the type of transformer to be adopted is very frequently determined by considerations other than strictly electrical ones. By this I mean not so much the choice between the core and shell type, but the choice between the oil-insulated, self-cooling, oil-insulated water-cooled, and the

air-blast transformers, also the single-phase or three-phase transformers. The questions of available water of the required degree of purity, available building space, transportation problems between the railroad and power station, etc., are taken into consideration in connection with the transformer problem.

Before leaving this subject, it might be well to mention the importance the transformer has in connection with station protection. Instances are on record where one-to-one transformers have been used merely as a means of added protection. The transformer seems to form a very effective barrier against the line surges or disturbances that frequently arise.

Station Layout. — No fixed rules can be laid down to be followed in the general arrangement of the equipment of a station. The topography of the building site, number and size of units, amount of high-tension apparatus, etc., all have an important part in fixing the most desirable arrangement.

In general, we may say that the best arrangement for a given case is the one which enables the operator to most readily control the plant equipment. If it is decided not to provide motors for controlling the gates, governors, etc., the switchboard should be located at the most accessible point from them. If independent direct current control can be provided on all of the station auxiliaries, the location of the switchboard with respect to the units is not of so much importance. However, as this is strictly a specific problem, little can be gained from a general discussion.

Water Measuring Devices. — Instances are by no means rare where no provisions have been made for measuring the water passing through a station. The speaker considers that weirs, installed under the proper conditions, are more necessary in determining the operating conditions than some of the switchboard instruments frequently installed. Compared with the total cost of the development, the additional expense required to provide means of accurate water measurement is very small indeed. Operating an hydro-electric plant without stream flow records is something like running a general contracting business without cost records. In neither case are we able to establish a ratio between the income actually received and that which we should receive.

Building. — The speaker has purposely said nothing about the building because he believes its design should be undertaken by the architect and not the engineer. After fixing foundation and space requirements, the engineer can well afford to turn the

detail designs over to a competent architect. It is quite essential that our building be inviting and attractive if we expect to succeed in developing new business as we should. This is especially true if our developments are accessible to the public.

DISCUSSION.

Mr. Markham Cheever. — This subject is an exceptionally comprehensive one, and has been most ably treated by the paper this evening. A few remarks might be made, placing emphasis upon the broad consideration of the thorough and economical use of stream energy, having in mind western conditions and western types of development.

The pioneer developments of the West were made largely to meet particular load requirements, without reference to the actual capabilities of the streams. The rapid growth of the country and increasing demand for power are requiring the utilization of the greatest practical amount of stream energy as well as the most effective conversion of it into usable form. Owing to wide variations in stream discharge throughout the year, topographical limitations and low load factors, a remarkably small percentage of potential water energy is made use of by existing developments.

The greatest loss of energy occurs through the unrestricted discharge of flood waters. Much can be done along the lines of yearly storage, but up to the present such developments have been largely confined to the smaller streams whose waters are used under high heads. With streams of large discharge, the problem of storing any great amount of flood water is a more serious one, and is sometimes impossible of any solution. A notable exception to this is to be found in the development work now in progress for the equalization of one of the largest streams of the Great Basin drainage area.

Owing to topographical considerations, at most, only a fair portion of the total drop of a stream may be made commercially available. Assuming that certain points of diversion and use are selected on a particular stream as forming a practical power site, and that the minimum flow, either natural or equalized, is known, the problem then becomes one of converting the greatest amount of daily stream energy into usable form. As the load factor of a market is always less than one hundred per cent., it becomes highly desirable to store energy at times of low loads for use during peak demands. By far the most practical method

of storing this energy is in the water itself. A dam that is high enough to divert water into a waterway usually forms sufficient reservoir capacity for peak load storage. With sufficient peak storage the water conductor and hydraulic apparatus should then be designed so that water is drawn only as required to meet the instantaneous load demand. This is the strongest consideration in favor of a pipe for flow line as against an open channel. With adequate equipment, peaks may be carried far in excess of the constant stream flow. The great advantage of this is obvious. In addition, this type of development makes advantageous use of high efficiencies in apparatus and equipment at loads less than maximum.

It should be mentioned that prior rights requiring a continuous return of water to the stream may necessitate a small equalizing reservoir below the station.

With a continuous water conduit from intake to power house, the problem of hydraulic regulation requires careful consideration. By hydraulic regulation is meant the acceleration or retardation of the long column of water with its corresponding decrease or increase of pressure in the pipe. For economical reasons it is advisable to run the flow line as close to the hydraulic grade line as the topography of the country will permit, making the penstock or pressure line as short as possible. The problem of regulation in the penstock is usually not serious. The velocity changes in the flow line may be properly taken care of by means of a standpipe located at its junction with the penstock. This standpipe must be properly proportioned. If too small, severe surging will result, and this may be aggravated by governor action to a disastrous amount. If of ample dimensions, the expense may make it impracticable. To meet the problem economically, Mr. R. D. Johnson has devised his "differential regulator," described by him in Vol. 30 of the Transactions of the American Society of Mechanical Engineers. A standpipe well designed upon his principle will apply the requisite accelerating or retarding head quickly and with little surging. Further, the size of structure is much less than that of a plain standpipe.

The continuous pipe line from diversion to power house is not the only method of meeting varying load demands efficiently. The topography of the country may permit of an ample storage reservoir at the head of the penstock, in which case the length of closed pipe connected to the turbines is usually not great enough to introduce regulation difficulties. The flow line

need then only be of sufficient capacity for the average flow and may be an open channel or pipe, as desired. Many western developments are meeting the problem of varying loads, to a greater or less extent, by means of small reservoirs at the upper ends of their penstocks.

There can be no rigid type of design. Each situation requires special treatment, but the ultimate aim should be to use the total energy of the minimum flow, and convert it into usable form with the best efficiency consistent with commercial considerations.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by August 1, 1911, for publication in a subsequent number of the JOURNAL.]

THE ELECTRIFICATION OF THE STEAM RAILROADS IN THE BOSTON METROPOLITAN DISTRICT.

[A Discussion before the Boston Society of Civil Engineers, March 15, 1911.]

The President. — We are to have as the subject for this afternoon's discussion the electrification of steam railroads in the Boston metropolitan system. One of our past presidents will talk to us from the point of view of a recent investigation of the subject. We shall also hear from a representative of one of the steam railroads.

Ten years ago I bought a piece of land and built a house on it on a side hill overlooking the railroad track. I never should have bought it in the world if I had not been convinced at that time that we were going to see electrification within ten years. I have inhaled smoke and had my share of noise ever since. The noise of the old engines they put there is almost unbearable sometimes. But I really expect we shall have to wait another ten years before we shall see electrification.

I suspect that this large gathering to hear a discussion of this subject this afternoon is partly due to the fact that a great many people in the metropolitan district have had experiences similar to mine. I suspect, also, that the same experience was the moving cause of the investigation which I am going to ask Professor Swain, former president of this society, to tell us about.

Prof. George F. Swain. — I feel sure I am not likely to be charged with appearing under false pretenses in speaking on the subject of electrification, because you all know I am not an electrical engineer. I cannot discuss technical electrical questions with you, or give you any information which is authoritative with reference to the proper system to be installed, or the proper voltage to be used, or any of the technical details involved in those questions. My standpoint is that of the engineer who considers the subject from the broadest possible point of view, as a financial and economic question rather than as an engineering one.

Now, in order that you may understand the situation, let me review very briefly some history. Last year the joint board on metropolitan improvements that was considering the report of a former special board on metropolitan improvements made

a preliminary report to the legislature, and in it recommended the passage of a resolve which should provide for a study by the steam railroad companies entering Boston of the problem of electrification and that the results of that study should be submitted to this joint board last fall. The joint board did not recommend the passage of any resolve going any further than that, but when the report of the joint board came to the legislature, the resolve which had been submitted and recommended by that board was amended by making it compulsory upon the board to present a draft of a bill which should provide for the electrification of all the steam lines in the metropolitan district within a stated time.

The legislature had apparently seriously contemplated the desirability of passing an act requiring the electrification of all steam railroads within the metropolitan district within a stated time. The joint board was requested to study the question and submit a draft of a bill for that purpose, and in accordance with that resolve the railroads prepared their studies and estimates, and submitted them to the joint board last November, and the joint board, being required to report early in January, had but a very short time to study the question.

Of course, our discussion had to be directed mainly toward the action suggested by the legislature; that is to say, a discussion of the wisdom and desirability of compelling steam railroads to electrify within the metropolitan district. I ask you, therefore, to bear in mind this point, — that we were discussing the question whether it was in the public interest to pass legislation compelling the electrification of all the steam lines in the metropolitan district within a stated time, independent of the construction of a tunnel or any other matter whatsoever.

The metropolitan district, as you all know, is an uncertainly defined area; that is to say, the metropolitan park district is one area, and the metropolitan water district is a slightly different area; and in any case it is simply an arbitrary district bounded by the boundary lines of certain towns. It has no relation to traffic or stations or anything except the boundary lines of towns — a purely arbitrary district.

I believe there is a great deal of misinformation with reference to this matter of electrification. As soon as we began to examine the reports of the railroads and to study the problem, I became convinced that there is a great deal of public misapprehension in regard to the matter, and it is very easy to see why there should be.

We can all agree, in the first place, that electrification is very desirable. We all want it and we would all like to have it. It has advantages both for the railroad companies and for the public. Mr. Bryant has referred to the smoke nuisance. Of course, we should all like to get rid of the smoke not only from locomotives but from all sources. The advantages to the public of electrification are mainly three. The first is getting rid of the dust, cinders, smoke and noise involved in steam operation. The second is the increased speed of transit that can be obtained, due to the fact that in an electric train the weight on the driving wheels is not limited; there can be a motor on each axle, and therefore there can be a greater acceleration in starting a train, and, therefore, in a given time an electric multiple unit train can carry passengers a greater distance with less delay. The limit within which a person can live and yet get back and forth to and from business within a reasonable time is, therefore, extended by electric operation. The third advantage is the improvement of real estate, to which Mr. Bryant has already referred. Of course, he need not have bought his house on the assumption that electrification would come and increase it very much in value, and I think no one should urge compulsory electrification, for which somebody else will have to pay, because it will benefit his property. But it illustrates the fact that it certainly would be a great advantage to real-estate owners to have electric operation of railroads. It would improve property along electrified lines. That is the experience in New York. In Park Avenue, where electrified trains now run, apartments which formerly were very disagreeable can now be occupied with comfort. The smoke, dust and cinders are entirely absent and the noise is hardly perceptible.

Besides, there are advantages to the railroads. They are admitted. In the first place, there is a saving in coal. You can generate your power in a large central plant and transmit it with only a small loss electrically to the trains, and in this way you effect a large saving in fuel. Then there is the saving in locomotive repairs. With a steam locomotive, when a single tube is out of order the locomotive goes into the roundhouse or the repair shop and is put in order. But in electric operation, if a certain part of the machinery is out or order, a new one can be put in without any difficulty and at much less cost and with less delay. There are other advantages. For instance, with multiple unit trains a saving is effected in switching in terminals. Further than that, with electric operation the tracks may be

covered. There is no need of a high trainshed. Trains can be run in one story and a high building built over that, for offices or commercial uses, so that the whole area over the tracks can be utilized. In some cases, this may mean a considerable item, and in other cases it may not. It is a problem by itself, a real-estate problem. The Grand Central Station in New York is improved in such a way that the tracks are to be covered by a high building, but the Pennsylvania Station is not built in that way. They did not find it desirable to cover the tracks with a high commercial building in this case. There are still other advantages I might mention if it were worth while, but I do not think it is worth while to go into them, as they are recognized.

In a long tunnel, of course, electric operation is now considered necessary. In fact, with our modern ideas, no one would think of operating in a tunnel in a city by steam. All the tunnels in New York and all the tunnels proposed in Boston contemplate electrical operation. The New York, New Haven & Hartford has begun to electrify the Hoosac Tunnel, thereby increasing very much the convenience and comfort of the passengers passing through it.

We all admit also that it is demonstrated that electrical operation is practicable from a mechanical or an engineering point of view. The New York, New Haven & Hartford and the New York Central are both operating heavy electric trains instead of steam trains in New York City. So that from an engineering point of view the problem is practical. It is, therefore, as I have said, not so much an engineering as an economic and financial problem, and that very soon became evident in our study of the question.

It is very important in studying a thing like this to take the broadest possible point of view. We should all be anxious to do what is best for the public welfare in its broadest sense. But the best of men, of course, will differ sometimes, and differ seriously, as to what really is best for the public welfare, and we must not expect to find absolute agreement on matters of this kind. I believe the majority of people are fair minded. I believe that if they really understand a situation they will take a point of view which is fair and right. But of course all of us are likely to make mistakes; all of us are apt to reason from insufficient facts, and all are likely to make mistakes in reasoning from those facts. We must cultivate a spirit of tolerance and patience in discussing matters of this kind. I think, however, that there are still a good many people who are not fair, and who,

if they want a thing, regard that as a quite sufficient reason for getting it, especially if they can get somebody else to give it to them. And some people take that point of view in reference to this question. We all want electrification; we would all like to have it and think we are going to have it some time. But the question the joint board had to consider was whether it was desirable to take action to compel the railroad companies to furnish this much-desired improvement.

Now the first point to be brought to mind in this connection is that it is very costly. The estimates from the railroad companies, for passenger traffic alone in the metropolitan district of Boston, aggregated \$40 000 000. Of course, to electrify for passenger traffic alone would not remove the smoke or noise nuisance, although it would remove it in part. Freight engines would still continue to be operated by steam and would still continue to give forth smoke. Remember, then, that \$40 000 000 would simply electrify the steam lines for passenger traffic in the Boston metropolitan district.

In addition to the large cost of electrification, there is the question of economy. The fact that we would all like to have a thing is no reason for saying we are going to get it. That is the point of view the child naturally takes. If a child wants a thing, he is going to get it if he can, and if he had the power he would make his parents give it to him. He wouldn't ask whether it was good for him. He wouldn't ask whether his parents could afford it. He wants it and would get it if he could. But when grown men want a thing they naturally take a somewhat different view, and they ask whether it is practicable and reasonable to get it and how soon they can have it.

The metropolitan district of Boston, with which you are all very familiar, is bounded by a line running just north of Lynn and Swampscott and shown on this map. It is a very irregular district, as you see. You will notice that the metropolitan district follows approximately the ten-mile limit or a little beyond. Toward the west it goes about fifteen miles out, and in one or two places goes a little further still. It is generally between ten and fifteen miles from the center of the city.

In that district the steam lines comprise some twenty-one radiating lines and branches. If you take all the steam branches of the New Haven, the Boston & Maine and the Albany, there are about twenty-one lines. Now, that is a very different condition from that which exists in New York. In New York we see electric operation. We say to ourselves, "If it is a good

Boston Metropolitan District.

thing for New York, it ought to be a good thing for Boston, and we ought to have it." No wonder we want it. But perhaps we have not sufficiently considered whether conditions are the same in Boston as they are in New York. In New York there are just three lines on the roads under consideration, — the New York Central and the New York, New Haven & Hartford, — just three lines radiating from the center of the city. They do not really radiate but run in the same general direction toward the north. The Harlem division of the New York Central runs north in a straight line. The main line of the New York Central branches from it and passes up the Hudson River, and the New Haven road diverges at Woodlawn and passes along the Sound toward Stamford. Those three lines run practically northward from New York City.

The map shows the result of the studies which were made by the steam railroads in conformity with the resolve of last year's legislature. The black lines illustrate the lines of electrification upon which the estimates were based. They have not gone in all cases to the limits of the metropolitan district, and in a few cases they have gone beyond. There is no reason why electrification should be made coincident with the metropolitan district. But you will note that they provide for the electrification of the Boston & Maine to Swampscott on the eastern division, to Wakefield on the western division, to North Woburn on the southern division, to Wayland on the Fitchburg division. The Boston & Albany estimated to South Framingham, together with the Newton circuit; the Boston & Providence to Readville, with the Needham and Newton Highlands loop, and the Old Colony system to Pemberton and to Scituate.

Now, that estimate, for passenger traffic alone, is $40 000 000. If it included freight traffic it would be considerably more, though not in proportion to the traffic, because, having power houses for passenger traffic, they could be designed to take care of the freight traffic also, and the freight traffic could be moved in such a way as to partially even off the load between the peaks. However, if you included freight traffic, you would have a very much larger cost than $40 000 000. That would provide for electrifying for an average distance of from ten to fifteen miles from the center of the city. In New York City, with an expenditure of $22 000 000, just about half as much as is estimated here, they electrified twice as far, carrying electrification over thirty miles from the center of the city.

The electrification of steam lines in the metropolitan dis-

trict of Boston would be electrifying the stub ends of through railroad lines. Steam trains would come in and when they reached a point ten or fifteen miles from the center of the city the locomotive would be disconnected and an electric locomotive would perform the remainder of the run to the center of the city. It is easy to see that in such a case the economy of electrification is a widely different thing from what it would be if the entire line were electrified. We see street railways and interurban roads run by electricity, and we are told they operate economically, whereupon we jump to the conclusion that it would be economical to electrify the steam railroads within the metropolitan district. It is astonishing how many people express the opinion that electrification of these lines would be economical to the roads, when they have no means of judging. Why, even an electrical engineer without experience in the operation of a steam road like these, and still less an engineer like myself, or a lawyer or a layman, could not pretend to say offhand, or from any study he might make, that this electrification would be economical. It is a thing that can only be determined by experience. That is the only possible way. And it is very clear that the electrification of one end of a steam railroad line is a very different thing from the electrification of the entire line. If you electrify an entire line you can dispense with your steam equipment, but if you electrify only the stub end you have to maintain your steam equipment just as it was before. You make no great economy in steam operation if you are going to run trains from New York or Albany or Bangor to within ten miles of Boston and there disconnect and run only the rest of the way by electricity. You make no perceptible saving in steam operation under those circumstances, but you take on in addition the expense of electrical installation. So it seems reasonable to suppose that a case like this would be a very different thing from the electrification of an entire railroad.

In New York the situation is much more favorable. If you could electrify for the entire locomotive run, so that you could save the entire run of a crew and engine, it might prove economical to do so. But if you electrify just a few miles you do not make a saving. In New York City they have electrified, as I have said, twice as far at little more than half the cost. They have electrified for a distance of between thirty and thirty-five miles. Now the experience the railroad companies report to us that they have gained in New York indicates that they do not make any saving by electrical operation. They say dis-

tinctly that it costs them more to run their roads as they are running them now than it did when they were running them by steam entirely. And nobody without experience in operating an electrified railroad can fairly contradict that statement. It is simply a question of experience and figures, and that is the result they give us. They tell us that not only does the installation in New York fail to earn any return on the capital invested, but that it also causes an increase in the running expenses of the road.

Now, if that is the case when they electrify thirty or thirty-five miles for three radiating lines, it seems reasonable to suppose that there would be a still greater loss if they attempted to electrify twenty-one different lines and branches and to carry the electrification only half as far. There seems no escape, therefore, from the conclusion that there would be an increased expense to the railroad companies, aside from the interest on the first cost of installing electrified service.

The above is one very important reason which led the joint board to conclude that at the present time it is not wise to exercise any compulsion in endeavoring to bring about electrical operation. The joint board, in considering this matter, did not arrive at a unanimous report. As I have said, the best of men, intent on doing the best thing for the public interest, will arrive at different conclusions in a matter of this kind. So this joint board did not arrive at a unanimous conclusion. The conclusion was unanimous on one point, however, and that is that it was not wise to pass any act requiring within a certain time the electrification of all steam lines in the metropolitan district. The majority of the board concluded that it was not in the public interest to pass any compulsory legislation whatever at the present time. The second minority of the board substantially agreed with the majority, but thought that further study should be made, further study by the railroad companies. And still another minority report suggested that some public board should be given authority to study the question and recommend the electrification of certain lines, or to require the electrification of certain lines.

Another consideration which led to that conclusion was the present state of the art with reference to electrification. Few of us realize how rapidly this has developed. Only about twenty years have passed since the first electric car was run. At the Chicago exposition in 1893 there was a small electric railroad running, and it was considered quite a remarkable

exhibit. Electrification of steam roads has progressed already faster in this country than it has in Europe, notwithstanding that in Europe most lines are owned by the state and the state can electrify and raise the revenue by its budget to pay the cost. And yet in a recent German report on the subject the author says the European governments have not seen their way clear yet to go very far in substituting electricity for steam.

The state of the art is such at the present time that no standards have been adopted, just as was the case with reference to the gage of tracks, car couplers, etc. As you know, the New Haven road has one system of electrification and the New York Central has another. One uses the third rail and the other the overhead system. Then again there are differences between various railroads with reference to the voltage, with reference to the cycles of the alternating current, and various other differences between the installations thus far made, which ought to be standardized. It is very desirable that these things should be standardized, because trains of one road may in the future have to be carried over the tracks of another road in a way that cannot now be foreseen. We all know the expense caused by the adoption of different gages of track. The same thing occurred with couplers and other standard railroad appliances. The joint board felt that until the art had become more standardized, it would not be wise to require the roads to expend such immense sums of money, part of which might in the future be found to have been thrown away. In order to enable the trains of one road to run over another road, standards are necessary, and should be adopted so far as possible.

One thing more with reference to trains running over different railroads. You are all familiar with the fact that the New Haven has petitioned the legislature for authority to build a tunnel under Boston Harbor, to acquire the Boston, Revere Beach & Lynn Railroad and to run its trains through to connect with the Boston & Maine, thus enabling them to run trains from New York over the Boston & Providence, under the harbor, and over the Boston & Maine to the Provinces and intermediate points. Suppose anybody thirty years ago, before the Providence Road had been merged with the Old Colony, had said then that through trains would be run over the Boston & Providence, the Revere Beach & Lynn and the Eastern Railroad, it would have been considered in the highest degree improbable; and yet this seems to be a thing which is tolerably near; it is a thing which may come about within a very short time. The next thirty years

will probably bring about changes of equal importance, which can be foreseen with as little accuracy as this change could have been foreseen forty years ago. We do not know what relations may exist between railroads thirty years from now, and it seems to me that something should be done to standardize before any compulsory legislation is adopted looking toward electrification; because if electrification is carried out under compulsion, the state becomes responsible in a measure for the waste of money which may result.

Then the broad question of regulation and compulsion is another thing to be considered. Nobody likes to be told he must do a thing. If a man comes to me and tells me I *must* do a thing, even if I want to do it, I have some reluctance about doing it, simply because he says I must. I suppose that is human nature. I think I am much more likely to decide not to do a thing if a man tells me I must do it. I think I might even refrain from doing it just because he told me I had to do it. I suppose we are all alike in that respect. The driver of a team, if he has a horse that is willing, does not lay on the lash if he is wise; he rather lightens the load.

Now our steam railroads here in Boston may, I think, really be called willing horses. Anybody who has followed the improvements that have been made in the last few years by the New York Central — the Boston & Albany — and by the New Haven Railroad knows perfectly well that those companies have expended voluntarily, without any compulsion, very large sums of money to improve facilities in order that they might give the public better service. Everybody knows that is true. The question, therefore, is how far it is wise to try to exercise compulsion. The joint board believed it was wiser not to exercise any compulsion. Personally, I believe in regulation of the railroads. I thoroughly believe in government regulation of the railroads, and I believe the government regulation which has taken place in the last few years, through the Interstate Commerce Commission, has been productive of excellent results. It has done away with evils which the railroad companies themselves were desirous of getting rid of and which they did not seem able to abolish, and it has brought about a much better state of affairs. But the broad public question involved is, How far should government regulation proceed?

The government regulation that has been thus far exercised has been directed toward three things, mainly: the regulation of capitalization; safety in operation — that is, the regulation of

safety appliances, the employment of standard couplers, the abolition of the car stove and the various other things which go to make safe operation; and, third, the regulation of rates. Now, those are all reasonable things to be regulated. The public ought to be protected against any possible attempt to charge unjust rates, and the public ought to be protected against dangerous railroad operation. Railroad companies which neglect to take proper and reasonable precautions to provide for safety in operation should be made to provide such safety.

It is worth while observing that electrification does not come within any of those classes. Electrical operation is not a matter of safety. It has nothing to do with capitalization in itself. It requires a great increase of capitalization, which I will refer to in a moment. It is a luxury which we would all like to have, every one of us, including the railroad companies. The question is, Is it wise to force the railroads to give it?

If any compulsory legislation is passed it will require, as you see, the expenditure of very large sums of money, $40 000 000 in the aggregate, for the metropolitan district; that would be spread over a term of years, but it is a very large sum of money. In considering anything like this, we must consider the moral effect of it in other parts of the country. If Massachusetts should pass any compulsory legislation it would probably be followed by other states. Boston is not the only place where the people have smoke which they would like to get rid of. Chicago, St. Louis — every large city in the country — is complaining of smoke, cinders, noise, just as we are. Now if other states should follow Massachusetts, and railroads all over the country should be required to electrify, you can easily see what an immense sum of money would be required. That money will not bring any additional returns to the railroad companies unless the traffic is very much increased. Remember that the experience in New York so far shows a loss in operating, aside from the interest on the first cost. If electrification would develop suburban traffic enough, — but it would have to be a very large amount, — perhaps the whole of it would in time be recouped. But nobody knows how long that would take, or to what extent the railroads would really profit. We all hope that, with the development of the art, economies will be found and that it will be found economical to operate by electricity. That cannot be done, it cannot be reasonably expected, if you electrify a large number of small branches ten or fifteen miles long at the end of steam lines. Economical electrification will mean electrification for a long run.

If we could electrify between Boston and Providence or Boston and Newburyport, or Portland, for instance, the railroads might realize some economies. But if they are required to electrify a large number of stub ends, their capacity to electrify long distances is just so much diminished. Our railroads require large sums of money to be expended every year for necessary improvements. We know that in 1906 and 1907 the railroads were not prepared for the great volume of business which came upon them at that time. I am told at the present time there is being handled by the railroads as much business as they were handling then, without special delays or obstruction to traffic. They have spent large sums of money since then. Of course, communities increase and railroad facilities have to be largely increased in consequence. Those improvements are necessary to handle the business of the country. Railroads have to provide additional tracks, and yards, and shops, and roundhouses, and stations, and rolling stock. To do this requires large sums of money, and in order to raise those sums of money private capital has to be interested, and largely foreign capital. What is going to be the effect upon the ability of railroads to raise these large sums of money which they need to carry on the business of the country if the states begin to require by compulsory enactment the electrification of certain parts of lines under conditions which apparently would bring in, for a considerable time at least, no increased revenue? Evidently investors will not be willing to put their money into railroad securities, and the business development of the country will be hampered proportionately.

We talk a great deal about the port of Boston and its possibilities. I believe we have the best harbor here that there is on the Atlantic coast. But we are at a disadvantage from the railroad point of view as compared with New York. Trains from the west over the Lake Shore and over the New York Central to Albany have very easy grades, and from Albany they can slide down hill to New York City without cutting their trains. But if they come on to Boston, they have to go over the Berkshire Hills, and an engine can only haul something like half as much load, or less than half as much, over the Berkshire Hills as it can haul over the Lake Shore and New York Central to New York City. We are at a disadvantage in Boston in that respect. What would be the effect if the legislature should require the expenditure of $40 000 000 or more to electrify just in the neighborhood of Boston? If the state requires an improvement of this kind, the state cannot refuse to allow the railroad companies

to raise the revenue to provide for it. If the state requires the railroads to spend $40 000 000, the state is morally bound to allow the railroads to raise the revenue, not only to cover operating expenses, but to cover the interest they have to pay. Where would that come from? It would not be fair to put it on traffic between New York and Albany and Chicago. It ought to be put where it belongs. Of course, the cost of a single item in railroad operation cannot generally be put on the particular traffic affected. But here is a case where it might be, and there might be reasonable ground to say that the railroads ought to be allowed to charge, not on the rate from Chicago to Albany, but on the Massachusetts business, a sufficient sum to make them whole on the investment from electrification in Boston.

If you are going to electrify for passenger traffic alone, and the cost is to be met by increased rates where it belongs, you will have to put the increase on the suburban passenger business. If you do that, you are likely to divert that business to the street cars. Right here in Boston the situation is very unfavorable in that respect. The electrified lines only extend generally something like ten or twelve miles from the center of the city. We have street cars running as far as that and farther. We have the Boston Elevated running elevated trains to Forest Hills and connecting there with various street-car lines. We have street cars running to Malden and Cambridge and connecting there with other lines, and the city of Boston is spending large sums of money, and proposing to spend larger sums, to build subways which will make it more easy for the people to get into Boston on street-car lines and to ride from the suburban towns and cities to the center of Boston for a single fare. Now, if you are to allow the railroads to raise the suburban fares, that might simply result in diverting traffic to these street-car lines; and, therefore, in order to raise the needed revenue, they would have to put the increase on long-distance traffic. In other words, the passenger from Boston to Chicago would have to pay more. Or you might have to put it on the freight traffic, or divide it over the entire road.

You see the difficulties, the various difficulties which have to be considered. You see what a broad public question it is, how many ramifications it has. It is by no means to be settled offhand. It is by no means to be settled by saying, "It is a good thing and we ought to have it. We don't like the smoke and we must get rid of it." The state of Massachusetts has recently passed quite stringent regulations with reference to

smoke. The last legislature passed legislation regulating the emission of smoke from chimneys, including locomotive stacks, in a way that would be detrimental, and a penalty is provided for violations of that act and a chief inspector has been appointed to see that its provisions are carried out. Therefore, the state has taken measures to do what it can to abate the smoke nuisance.

You see the ramifications of the problem, and what a difficult one it is to solve. The majority of the board felt that under all the conditions it would not be wise to attempt to pass any compulsory legislation, and they felt that especially because they believed that if it were left to the railroads themselves the problem would work itself out in the very best way. And their faith seems to have been vindicated in a measure since the report was written, for the New Haven railroad has applied for authority to build a tunnel under Boston Harbor, to purchase control of the Revere Beach & Lynn Railroad and to electrify from Readville to Lynn and beyond. Of course, they would have to electrify the tunnel and therefore to electrify for a reasonable distance at either end. There is the beginning of electrification, and that will extend gradually and we hope rapidly. We hope the state of the art will be improved and economies found. No one would be more pleased than I to find electrical operation more economical than steam. But it has not been proven so up to this time, if only, or mainly, short ends of through lines are electrified.

I hope in considering this you will realize that it is necessary to take a broad view. We are all looking for the public interest, but the public interest must not be confused with our own personal interest in desiring to get rid of smoke. There is a much larger interest. If capital should be deterred from investing in our railroads it would be a very unfortunate thing. In closing I want to quote from an interview with probably the leading English authority on railroad matters of this kind, — Mr. Acworth, — who has written several books on railroads. He paid a visit to this country recently and in February, just before he returned to Europe, he gave an interview, in which he said, "In economy of operation the American railroad is first in the world." He expresses surprise at the space given by newspapers to criticisms of railroad officials, and dwells upon the enormous amount of money that must be spent on American railroads in view of the fact that facilities must be increased at least fifty per cent. every ten years. Most of this capital, he said, must be obtained abroad, and if investment is deterred by what he regards as too much legisla-

tion and governmental interference, it will be a bad thing for the country. I believe that is absolutely true, and for that reason I was very glad to sign the majority report of this board. It is against compulsory action by the legislature, believing that if the railroads are left to themselves they will work the problem out in the very best way.

The President. — I am quite a believer in railroad engineers. I have not altogether the same opinion of the abilities of railroad managers, certainly not the opinion that Professor Swain has given. One of the railroad engineers is with us this afternoon and will tell us something of what the New Haven road has done and is doing. The New Haven road, as you know, is not waiting for compulsion. It is already installing electrification in various places. I take great pleasure in introducing the chief electrical engineer of the road, who has this matter in hand, Mr. William S. Murray.

Mr. William S. Murray. — I feel it a very great honor to be called up from New Haven to address you here to-day. Six years ago I was able to number myself as one of Boston's inhabitants, and at that time was a very happy man doing engineering around here, when the call came to consider the question of what the New Haven should do in the way of electrifying its lines, in view of the then under way electrification that the New York Central had inaugurated, from Grand Central Station to Woodlawn.

I came here with two distinct speeches — one with reference to what I have to say about Boston; the other, pictures. Now, it seems to me, the pictures are all I have left. I wish to say that I have listened with the very greatest interest and instruction to the gentleman who has just preceded me. He has taught me a great many things in relation to this situation in Boston, and I should like to take this opportunity to express my gratification at being relieved in this remarkable manner from bringing the features of the situation he has discussed before you this afternoon. The whole thing, it seems to me, is epitomized in what he has had to say concerning the necessity of the steam road to carry, while reaping some of the economies of electric traction, the tremendous fixed charge that is already attached to that road.

Were you to say to me, "Mr. Murray, I should like to have you lay your plans for a new railroad from New York to San Francisco, and tell me which would be the cheaper, electrical or steam operation, again provided that certain power houses

could be erected with ability to furnish power at a reasonable cost," of course I should be prepared to say the electric form of traction would be unquestionably the cheaper. In such a case none of the burdens incident to the steam-road electrification would have to be carried.

Again, I should like to call attention to Professor Swain's remarks with reference to the peculiar layout of conditions that are here in Boston. The New York, New Haven & Hartford, the New York Central and the Pennsylvania, as you know, have electrified in New York. They are in each instance feeding electricity into great trunk lines and handling trains of great density thereon. The train density on those lines is enormous, and thus it is perfectly patent that a line that has been put up to serve three hundred or four hundred trains can very much better carry its fixed charge than a line that would have two, three or four, or possibly fifty trains to serve.

We haven't had sufficient experience with electrification to get as yet a full perspective of what it stands for. In the part of the Boston & Maine on which electrification is contemplated, we see seven devious routes going out from the center, and on the New York, New Haven & Hartford there are six. Thus, comparatively speaking, a very light density of traffic must obtain on each line or route. Professor Swain's dispassionate appeal ought to have very serious consideration, for the problem seems to be a very difficult one, one in which men and not children or enthusiasts are involved. I venture to say there is no man in this room who is more enthusiastic on the subject of electrification than the speaker. My life is wrapped up in the matter of electrification, and I just await the word of Mr. Mellen to say, "Go ahead and electrify." I should like to see the whole Boston metropolitan district electrified. But viewing it from the non-enthusiastic point of view, from the point of view of reason, I can see perfectly well that a mandatory act to-day is certainly not wise either for the city of Boston or for the railroad.

As I have said, that part of the situation has been fully covered by the professor's splendid address. I have come to you to-day absolutely unprepared to speak on this subject of electrification, but rather with the thought of a heart-to-heart talk among engineers. It has usually been my fortune to address electrical men, but it is a great privilege to be able to say a few words to brothers in another branch of the profession, whatsoever it may be.

When called to New Haven for the consideration of this

matter of electrification, six years ago, I confess that the day I arrived there I had my mind pretty well made up in one direction, but I knew that if the result of careful investigation proved that that direction should be changed — so it would be. I knew, too, that alternating current had supplanted direct current wherever a large amount of power and its distance of transmission was large, and it seemed to me that there was no place where it was so exemplified as in the case of the railroad. What greater emblem of just that combination is there than in the South Station to see marked on the signboards of one of our 800-ton trains: "New York." That means that a large amount of power has to be constantly supplied to that train over a long distance. If high voltage and small current is transmitted over our western mountains for hundreds of miles, why not over our straight-away railroads? And while I say this, I wish in the same breath to say that direct current has, in my judgment, a perfect place in which to practice its already splendid results, that is, in the cities and in the interurban territory between. There is nothing more economical in principles of operation than the direct current for this locality. It has been with us twenty years and it has gradually risen to the pink of perfection — a magnificent piece of power-producing electrical machinery. So let us keep in mind the places where the different classes of current should be applied. In the case of trunk lines, where long distances are involved and heavy units of power required, such conditions are unrelated to traction necessities in city streets and between towns; it is an island proposition. It is in a class of its own and must be treated as such.

Thinking in that direction I went down there, and after a very careful investigation of nearly nine months, it became apparent that the alternating current met the requirements of the service. I do not wish to animadvert upon any other system, but I think this is a time when we must agree as to the proper place for the different forms of electricity. I have had it said to me, "Mr. Murray, this is no time to show the railroad men that we disagree about this matter among ourselves. If we fellows can't agree among ourselves, it will be pretty hard for the railroad man himself to be able to size up the situation." Gentlemen, I think that is an absolute confession of weakness and cowardice. I have had six or seven years' association with railroad men in the departments of finance, maintenance of way, engineering and transportation, and I haven't met any of these decrepit cowards yet. I have found them men who are able, after the presentation of a case, if it is clearly presented, to size it up.

Professor Swain spoke a moment ago about standards. I think to-day is the time when we have got to decide on a primary system for trunk lines standard to all railroads.

When the question was taken up by the New Haven road what type of system should be used, the question was asked: "What is this, a terminal, a suburban or a trunk line proposition? And how far are you going?" And the answer came with the usual advance wisdom of our good president, "I want a system that is good for extension to Boston." That settled it for me. That was what I wanted to know. And we have got that system.

Now, the laws of hydraulics are not unlike those of electricity, and I will try to speak in terms of hydraulic units to represent those in electricity. You gentlemen know very well that if you have a high head of water you are able to deliver a very large amount of water with a small pipe. You also know that in delivering that water with a high head, if you wish to turn it into power, the products of your head and your flow divided by a constant gives you the horse-power.

Again, to illustrate with the water pipe, the same amount of power can be delivered from a pipe of low head as from one of high head, providing the low head pipe is sufficiently large to deliver the greater quantity of water required. In the case of the small pipe with the high head, it simply delivers a small amount of water flowing rapidly, while the large pipe with the low head delivers a large amount of water flowing slowly; the product of head and quantity of flow being the same in each case. But you also know that if you have any distance to transmit your low head of water in the pipe, it will have to be a very large one. Otherwise, you will not be able to develop much power at the end of the pipe.

Now it is the same with electricity, in transmitting at high pressure, the power is developed at the other end of the line, with the consumption of a very small amount of current, and the law of loss in the wire is like the law of loss in the pipe. The actual loss of a given system varies as the square of the voltage, provided the same amount of power is delivered. If I were transmitting a certain amount of horse-power by using 100 volts over a given transmission system, and I elected to double that voltage, I could deliver the same amount of horse-power under the higher voltage with 25 per cent. of the loss I had before. In the case of the single-phase installation we have put in, on account of the high voltage used there is not a substation all along the whole line. The result is that when trains come in

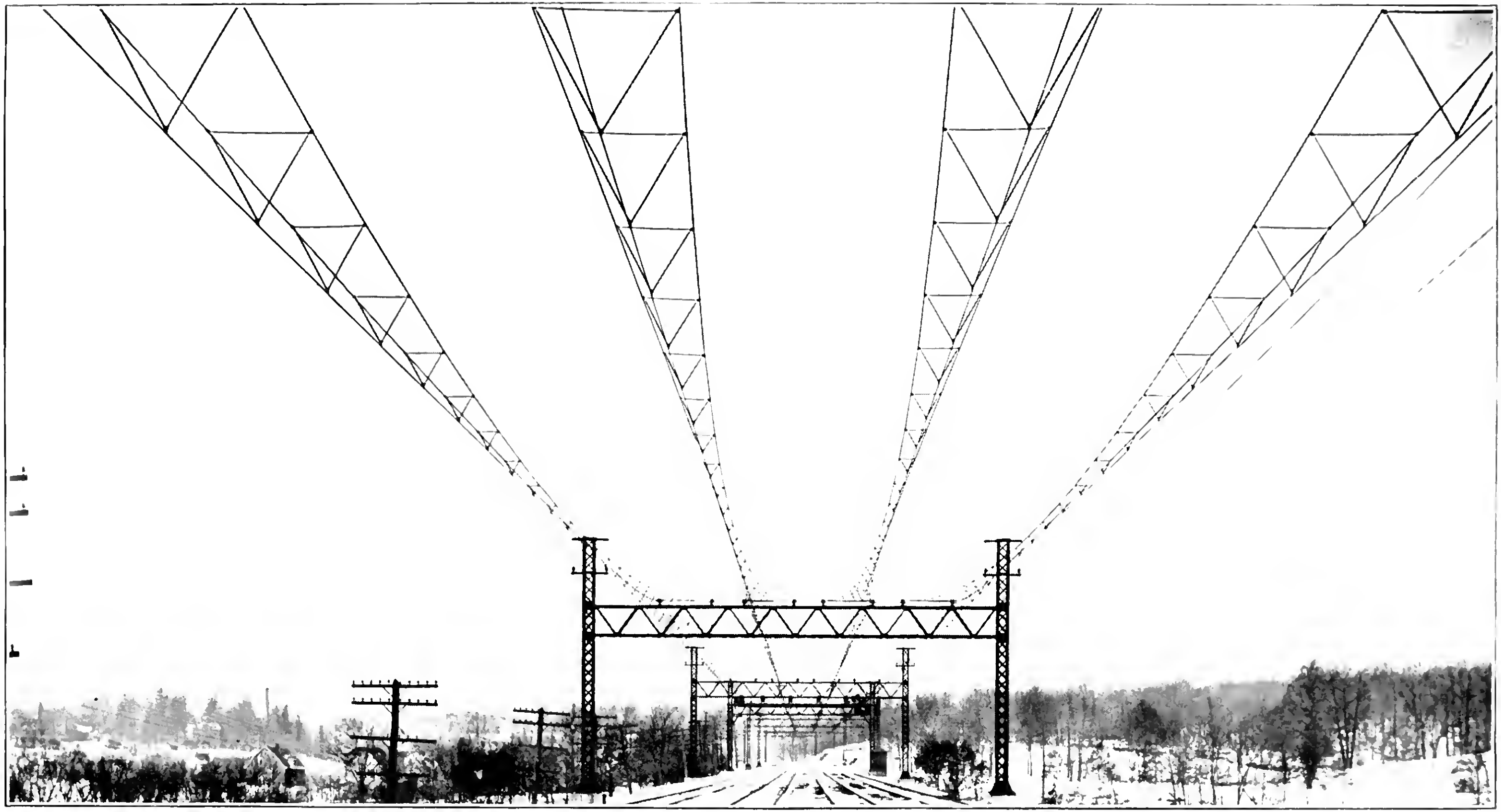
from Woodlawn at the junction of the New York Central with the New Haven they get power from a single station eighteen miles away. Naturally the omission of all substations stands for a tremendous saving in our general operating cost. Had we used the direct-current system, besides the power house we should have had to have four substations.

I have just touched on these little points of difference between systems, and why we elected the single-phase system, to give you an idea of the characteristics of the single-phase system before I show you some lantern slides of our construction.

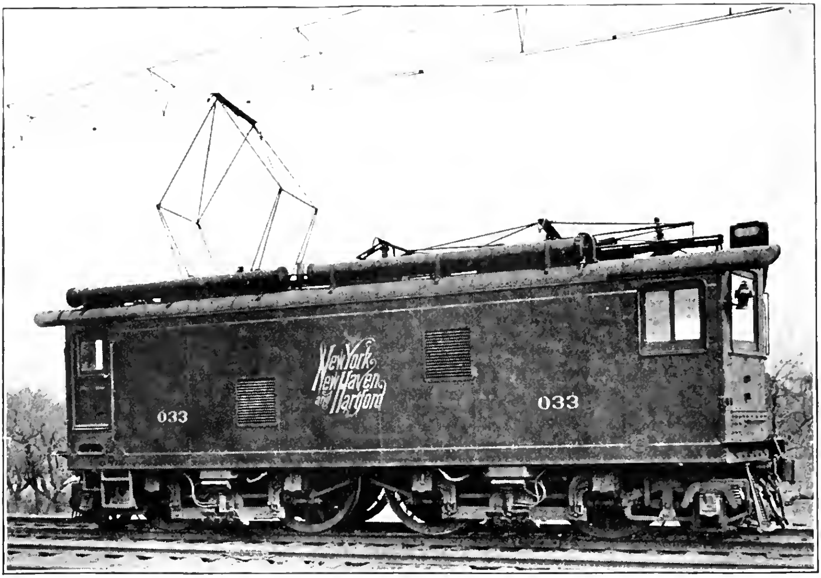
It has been remarked by some who are not closely in touch with the facts concerning electrification that the locomotive repairs and fuel saved by electric traction are sufficient in themselves to cover the interest on the cost to electrify. Now, gentlemen, that is a pretty statement, but as we are all engineers here we can talk plainly on that point. That *could* be possible, if the density of traffic were sufficient, but it does not apply to the New York, New Haven & Hartford Road, even with the density of its lines between Woodlawn and Stamford; far less to the Boston situation when the traffic is spread over so many devious routes. Such an erroneous statement may lead to a thought about as follows: "Here is the metropolitan district. If they can save enough money to cover the interest on their investment simply by what is saved in locomotive repairs and fuel, why don't they electrify?" A good argument for those who haven't given the problem any good, hard thought, and I think it is a very important point to be brought out. Yet I wish to say to you, who can analyze and assign proper values to advantageous factors, that it is in these two departments that electrification is going to pay, if it does pay.

There is one other department which is very interesting where savings are to be effected, and that is in the inherent ability of the electric system to increase the train movements in yards and terminals and on suburban roads. No one knows better than the railroad man that the saving of a train mile is a very positive saving. And so, if you can turn your equipment over more quickly by making higher speed, and using greater train weights, why then the combination of these two affords an opportunity of saving train miles.

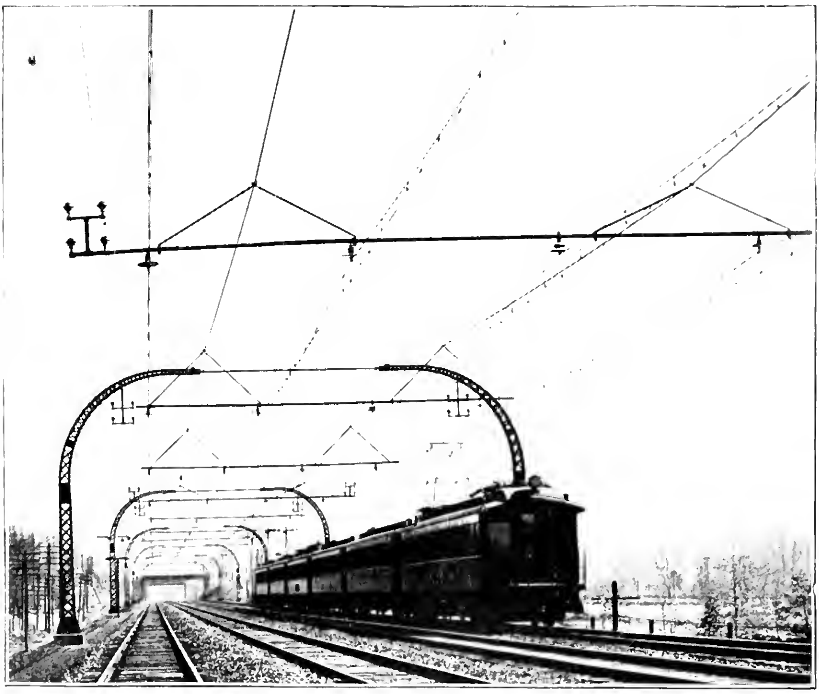
Professor Swain said you might possibly be interested in knowing what we have done in the matter of electrification, and I would say on that score that at present we have about 100 miles electrified between Stamford and Woodlawn, measured on a



Double Messenger Single-Phase Catenary Construction on the N. Y., N. H. & H. R. R., between Woodlawn, N. Y., and Stamford, Conn.



N. Y., N. H. & H. Passenger Locomotive.



N. Y., N. H. & H. Multiple Unit Train.

single-track basis. As you all know, we electrified in those early days simply to cover our passenger operation, and no freight trains except upon an experimental basis have been operated by electricity. On the Harlem River branch there are about 61 miles of single track, and there is in yards attached to that branch a mileage approximating 100 miles; this is now being electrified. Also the New York, Westchester & Boston is being electrified. This road is a four- and two-track group which meets our Harlem River branch at West Farms and runs out through the Mt. Vernon district to North White Plains, with a branch to New Rochelle. These three systems are all to be constructed in a similar way and the power supplied from one source, thus showing the reach of the alternating current system. I think it is not uninteresting to say that at the Harlem River yard, 25.6 miles from the power station, when 5.30 comes along with its suburban traffic load, the voltage will not fall below 9 000 volts. With that voltage and the flexibility of the single-train system, the schedules of trains can be absolutely maintained. You will be interested also to know that on football day at New Haven, when our loads run to a maximum of something over 20 000 horse-power output, at the power station, the actual average transmission loss for the whole day was approximately 3 per cent. A very, very heavy load at the end of the line at Woodlawn showed a momentary drop of about 14 per cent.

Now, as to operation. Naturally when one has in mind to standardize, before we do anything in this direction it is quite essential to show just what kind of operation the system to be standarized can give. I have been working out some train delays to find the total distance a train would travel and suffer a delay of three minutes. You are fortunate to be sitting down, gentlemen, because I think if you were standing you would be taken off your feet by what I am going to tell you — for it sounds almost impossible. But I found that a train would travel from New York to San Francisco and back eleven times with a delay of three minutes.*

PROF. DUGALD C. JACKSON. — I will speak out of experience with city street railways and interurban railways on which electric power has proved its usefulness beyond cavil.

---

* When I addressed you I said the delay would be one minute, but this was based on an average delay rate. On further consideration I think it is fairer to state the actual delay for an accomplished mileage of 66 000 miles. In the month of November, 1909, this electric locomotive mileage was run off consecutively with a total delay of three minutes.

The conditions of steam railroad operation differ widely from the conditions of street railway operation, and also differ sufficiently from the conditions of the usual interurban railway operation, so that deductions drawn from these cannot without modification be applied to the conditions required for the electrification of the steam railroads which operate about Boston; but my remarks will be made with full consideration of these differences.

My regard for Professor Swain, who was a member of the majority of the Joint Commission on Metropolitan Improvements (which is colloquially called the "Big Four" Commission), and my respect for his ability and thoroughness as an engineer, make me regret to differ from the conclusions which he must espouse when he expounds the views of that majority, but many of the grounds which the majority of the commission have laid down as the basis for their argument seem to me to be doubtful or at variance with the best engineering experience.

The majority report urges that because electrification has not yet been reduced to standards, its use for the Boston service is of doubtful expediency; but Mr. Murray's pictures, of which he has a large number, are sufficient to prove to an audience of engineers that the electrical structures are sufficiently standardized to meet the requirements of service. Moreover, Mr. Murray's statistics are sufficient to prove also to an audience of engineers that the reliability of electric service in the great electrification which the New York, New Haven & Hartford Railroad has constructed and is operating for the purpose of conveying passenger trains into and out of the terminal at New York City is equal to, if not greater than, that obtainable by the use of steam locomotives. Corresponding information comes from the important tunnel electrifications of the Great Northern and Grand Trunk railroads and the Long Island and New Jersey electrifications of the Pennsylvania Railroad.

It is urged in the majority report of the commission that the results of the operations of the New York Central Railroad and the New York, New Haven & Hartford Railroad at the New York terminal show that electrification has not there proved financially satisfactory, and that the Boston situation imposes more difficult and expensive conditions which would make electrification an excessive burden to the railroads. In support of this argument, the report states that there are only three lines of railroads running out of the Grand Central Terminal, while there are twenty-one radiating lines out of the two Boston terminals. It is to be observed, however, that the twenty-

one lines radiating out of Boston are not twenty-one independent lines, but comprise some seven or eight principal lines which radiate from the terminal stations, and the remaining lines comprised within the twenty-one are branches of these principal lines. It is also to be observed that a number of these branches are largely given over to suburban passenger traffic, and that their natural electrification termini would be at or beyond the ends of the dense suburban service at which suburban trains complete their runs. In consequence of this condition, the difficulty in regard to engine stages and the location of engine sheds is not a new problem in the operation of these lines and is less serious than the majority report of the commission seems to infer. Engine houses must now, with steam traffic, be maintained at or near these points where the suburban trains complete their runs; and that will doubtless always be true whether or not the lines are electrified. The difficulty in respect to engine stages, therefore, does not seriously extend to a good part of the suburban traffic, although it does apply to the relatively smaller number of through trains and some suburban trains. The question of engine stages for the through trains is a very important one, and should be given full weight in a discussion of this problem, but it should be recognized that the main part of the problem has already had its solution by the railroads in connection with their existing suburban steam service. With this existing condition the radial character of the Boston lines may actually give an advantage in favor of electric operation, rather than the reverse.

The passenger traffic in and out of Boston is much greater than the traffic in and out of the Grand Central Station at New York, which the majority of the commission uses as a basis of comparison. Taking the figures which the commission has published with its report, it appears that nearly sixty million passengers are now handled per year at the North and South stations together, and that only twenty million passengers are now handled per year at the Grand Central Station in New York. In other words, nearly three times as many passengers are handled over the lines radiating out of Boston as over the lines out of New York. It may also be observed that the commission's tables show that the investment required for electrification per train mile run about Boston, as estimated by the railroads, is less than the corresponding expenditure for electrification on the lines extending from the Grand Central Station in New York. The extended report of the majority of the commission states

that the investment required for the electrification per train mile run at New York is \$2 870, while the corresponding figure is estimated to be \$1 800 for the Boston & Albany Railroad at Boston, \$1 880 for the New York, New Haven & Hartford Railroad at Boston, and \$2 540 for the Boston & Maine Railroad at Boston. It therefore appears that the railroads' estimate of investment required to make the complete electrification of their lines about Boston is \$1 000 per train mile run or 35 per cent. less for the Boston & Albany Railroad and the New York, New Haven & Hartford Railroad at Boston than the corresponding unit cost of the electrification of the New York, New Haven & Hartford and the New York Central railroads at New York. Accepting the estimates of these railroads as given, it seems that the electrification might be a financial success at Boston for the Boston & Albany and the New York, New Haven & Hartford railroads even if it has failed to prove a financial success near New York. In respect to the latter, however, information now at hand is not conclusive in support of the commission's majority view that the electrification about New York cannot earn fair returns on the investment. The conditions of operation about New York have heretofore been particularly costly, — first, because the original construction has scarcely been completed; and, second, because of costly conditions associated with the operation during reconstruction of terminals which is still going on. There seems to be no substantial claim that electric service has not been as reliable as or perhaps more reliable than steam service, or that locomotive costs *per se* per train mile have not been less expensive with electrification than with steam, since the electrifications about New York have come into fairly permanent operating condition. Moreover, the service of interurban roads and elevated roads shows clearly that the operation of frequent suburban trains can be carried on more satisfactorily with multiple unit electric trains than with trains drawn by steam locomotives. These various grounds make it appear likely that the majority of the commission overestimated the cost of electric plant and underestimated the economies which may be derived from electrification.

Of the four commissions sitting jointly to compose the "Big Four" joint commission, the Railroad Commission is composed of gentlemen appointed to supervise the affairs of the railroads, and that commission has spent many years in its duties of observing and supervising the activities of the roads. It may be presumed to be more fully acquainted with the finan-

cial capabilities of the railroads than any other men in the public service of the state. The Transit Commission has been for years employed in constructing subways, tunnels and like structures for the local transportation of Boston, and may be presumed to have a reasonably complete knowledge of the local transportation problem. The Harbor Commission presumably has given its attention more to questions associated with harbor facilities, and the Park Commission may be presumed to have been giving its attention particularly to the extension, improvement and maintenance of the Metropolitan Park System. It is not to be expected that the gentlemen of the last two commissions should be expert in respect to transportation problems or in respect to the ability of the great steam railroads to support financial expenditures. With the highest respect for the individual members of the Harbor Commission and the Park Commission, we must yet recognize that the interval available between the time when the railroads presented their electrification reports as required by legislative enactment and the time when the commission was under obligation to present its report to the legislature was too short to enable a man not already well informed on transportation matters and the financial status of the railroads to become so adequately informed as to become an effective adviser thereon for the state. It may, therefore, be assumed that the men on the joint commission most capable of judging the problem are those composing the Railroad Commission and the Transit Commission. Of these gentlemen, every member of the Railroad Commission and three out of five members of the Transit Commission dissented from the majority report. It may, therefore, be assumed that the contention of the majority that the railroads cannot now bear so heavy an expenditure as would be required for electrification is unsustained. The careful members of the Railroad Commission would not sign a report recommending an immediate beginning of electrification or even further study of the processes for bringing about electrification unless they believed that the railroads are able to bear the cost when the work is carried out gradually.

Another argument of the majority report runs to the effect that economic conditions will not warrant pressing the railroads toward electrification by means of legislation, and that the railroads ought not to be pressed in the direction of providing a luxury. There are, however, good grounds for disagreeing with the classification of electrification of the Boston suburban railroad service as a luxury, especially when those broad economic grounds which affect the entire public are considered.

The smoke nuisance has been talked of a good deal, and it is briefly discussed and dismissed in the commission's report. This brief treatment does not seem an adequate treatment for a factor of this importance to the public welfare. While little specific information is available in regard to the effect of the smoke nuisance in and about Boston, it is incontestable that large quantities of smoke are in the atmosphere, and that the city is made dirty and objectionable, especially on certain days, as the result of smoke and cinders which have been artificially discharged into the atmosphere. One large American city has gone into an investigation of the extent of the smoke nuisance induced by steam locomotives. "Smoke inspection" has existed in that city for many years, and the inspection is supposed to be reasonably effective. It is reliably reported that the inspection has resulted in a marked reduction in the amount of smoke and dirt in the city. The smoke inspection department of that city has gathered statistics on the various sources of smoke still being discharged into the atmosphere, and the conclusions include the following: That approximately 18.5 per cent. of all the coal consumed in that city is consumed in the locomotives within the city limits; that this 18.5 per cent. of the coal burned makes 43 per cent. of the total smoke, notwithstanding careful inspection; and, because locomotive smoke consists of a larger percentage of cinders and dirt than the smoke emitted from ordinary industrial or domestic chimneys, it is estimated that more than 50 per cent. of all the dirt arising from coal consumption within the city is caused by the locomotive smoke.

In case a similar condition exists in respect to Boston, and the statistics are not forthcoming to show that it does not exist, it is impossible to say that the effect of locomotive smoke on the public welfare of this city is not a matter of economic importance; and the question may be seriously considered whether it is not of sufficient economic importance itself to remove the electrification of suburban steam railroads out of classification as a luxury. This is a factor in addition to the advantages of increased taxable values from property relieved from the nuisance of railroad smoke and cinders.

Turning to another factor of the broader economic aspects of the question, namely, speedier service which may be obtainable through the better control of suburban electric trains compared with suburban steam trains, the following considerations may be suggested. Nearly sixty million people are handled in

and out at the North and South stations per year. This is an average of over 90 000 people who come in and who go out each week-day in the year. If each of these 90 000 people may save five minutes in the round trip of each day on account of the speedier control of suburban trains operated by multiple unit electric service substituted for steam service, and the average earnings per person may be assumed to amount to $1 000 per year, working eight-hour days, the economic value of the time saved to the community, without taking into account other advantages to the individuals, would pay a considerable fraction of the interest on the electrification. This may perhaps be thought to be too theoretical to be credited as an argument, but when it is remembered that adding to the convenience of the travelers and saving a few minutes daily of each one's time is one of the prime reasons for which the city of Boston or the state has spent and has authorized the expenditure of large sums of money (aggregating some $20 000 000 in round numbers) for Boston subways and tunnels, without including the subway in Cambridge, and in addition thereto there are the known facts that the use of multiple unit suburban trains instead of steam trains reduces the terminal trackage and terminal train movements required to meet the requirements of a dense suburban traffic (which would give needed relief to the now crowded terminal tracks and stations in Boston), and that the ways may be covered with streets or with buildings where desirable, without inconveniencing the train operation, it becomes obvious that a broad economic question exists which may appropriately be given attention by engineers as well as the general public.

It is necessary, however, to bear constantly in mind that transportation and intercommunication are projects upon which economic progress essentially rests, and it would be a disadvantage equally to the individuals of the general public and to the railroad stockholders if electrification were crowded upon the railroads more rapidly than they are able to effectually carry it out. There are great difficulties in the way of the complete electrification of all lines entering terminals like those of Boston. These difficulties may be and will be overcome. This is plainly indicated by the courage and success with which the New York, New Haven & Hartford Railroad attacked and overcame the then tremendous difficulties which they faced several years ago upon adopting their system of electrification for operating passenger trains between the Grand Central Station and Stamford. Nevertheless, it would be disastrous to push the problem of

electrification faster than the railroads can solve it, and care must be taken to be reasonable while pressing the project forward.

The railroads themselves desire partial electrification. The New York, New Haven & Hartford and the Boston & Maine organization desire to operate a tunnel connection from near the South Station to East Boston; and, in case this tunnel is built, they will find it necessary to electrify at least that portion of the road. This tunnel, built under proper conditions, will sufficiently improve the through facilities of the railroads as well as afford conveniences for the local freight and passenger transportation of Boston, so that its early completion is very desirable. The tunnel may well be built by the state and leased for the use of the railroads, as is proposed by the Chamber of Commerce, but it seems reasonable as well as appropriate for the state to expect the railroads coincidently to extend electrification beyond the mere requirements for tunnel operation, by making a start upon the electrification of the suburban lines, beginning with those on which the traffic is heaviest and on which the disadvantages pertaining to the existing steam service affect the greatest number of people. Electrification is bound to come, but I am ready to agree with the sentiment of the minority reports of the "Big Four" Commission, namely, that the complete installation ought only to be brought about gradually. This can be effected by legislation which requires the early completion of a certain proportion of suburban electrification associated with the tunnel electrification. The extension of the electric service to the other suburban lines will then inevitably follow from the necessities surrounding suburban train operation, and by the force of public opinion pressing further legislation forward as reasonable opportunities arise. In order that the force of public opinion may be directed to practical ends and thereby accomplish a useful result, the Transportation Commission which has been proposed before the legislature would be of inestimable benefit, and I call your attention to the proposal as worthy of every citizen's support.

By the logic of the situation, it seems to me that the majority of engineers who are familiar with the possibilities of electrification and who carefully examine into the needs of the Boston service must come to agree with the unanimous recommendation of the minority of the Joint Commission. The minority divided and made two reports, but agreed in the opinion that the subject of electrification is appropriate for legislation. Five men of the minority are of the opinion that some legislation should be now enacted to require a prompt beginning of the electrification,

but allowing latitude to the railroads for the prosecution of the work in a manner which will not embarrass their traffic or injure their credit. It would obviously be undesirable to press the matter of electrification of the lines too rapidly, since an injury to the credit of the railroads might make it necessary for them to withdraw from other improvements which are desirable.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by August 1, 1911, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF PAPER, "THE COMPRESSIVE MEMBER."

(Volume XLVI, Page 234, March, 1911.)

Mr. John Severin Branne. — I have read with much interest Mr. Horton's comprehensive review of large-sized compression members, as compared in detail with smaller ones.

While it is not the good fortune of all to deal with the large, we may be permitted to add our experiences in smaller matters, belonging to the same class of objects, and working for the safety as well as economy in construction.

The object in the compression member is to get the greatest enduring strength with the least cost. Generally the least first cost is contingent upon the greatest strength with the least metal, and this is favored by the spreading out of the sectional area, giving a large moment of inertia in all directions. But there are several limiting conditions to this, thus:

(*a*) Thinness of Metal.

(1) To secure strength at the ends, in making proper connections, whether in the number of pin plates or of plates for direct bearing, the plates may become very long, owing to the original extreme thinness of metal, and thus interfere with other connections; or the percentage of detail will run too high for economy in fabrication.

(2) Where beams, floor beams or brackets have to be connected to a thin web or to several thin component members, similar objections as mentioned in (1) occur; excessive weight of detail, caused by low bearing value of rivets and necessity of stiffening diaphragms and cover plates to distribute loads as uniformly as possible.

(3) In exposed structures, or even covered ones, subjected to acid fumes, due allowance must be made for deterioration by rust, destroying a greater percentage of the thin than the thick section.

(4) The thin section, in itself amply strong to resist ordinary dead and live loads and deterioration, is more apt to suffer from accidental mechanical injury, blows, shock, twists, etc., on loading platforms and other places where bodies in motion may deflect and strike the member.

(*b*) Greater Cost of Fabrication.

As the light sections use lace bars on two or four sides, constituting little weight and much shop work, the unit cost will rise. Further, the lace bars only hold component parts and furnish no effective area.

(1) Hence, for simple uses, as for building columns and bridge posts, there is clearly a limit where the laced member becomes more expensive than a solid one, as the advantage of higher unit stresses allowed for a higher radius of gyration afforded by the component laced parts is set aside by the increased cost per pound of such member over the solid one, meaning by solid a member where cover or web plates are used to the exclusion of lace bars.

(2) Again, in short columns, especially building columns, requiring at all times a solid section at the ends, and often solid at intermediate points, to take connections, the saving by laced section is less pronounced.

(*c*) Homogeneity of Section in Resisting Loads.

Either the solid or laced column seems to stand equally well for short columns. The tests on Z-bar columns described by Mr. C. L. Strobel, M. Am. Soc. C. E., in the Transactions, Volume XVIII, showed that four Z's laced in one plane (two rows of rivets) gave ultimate strength close to the elastic limit. The uniform thickness of metal in the Z column, or as imitated by built-up plates and angles, seems to help the strength, as the laterally unsupported flange, only $2\frac{1}{2}$ in. wide, was very narrow compared with the length of the column.

Compression members with one web and four angles or one web and four Z-bars are the cheapest to build and have the advantages of ease in inspection and painting, and through web connections for floor beams or wind-bracing gussets; they are limited in use by maximum sections attainable.

The compression member of box section generally costs a little more to fabricate but takes slightly less metal than the former class. It is better adapted for building up large sections, but precludes subsequent inside inspection and painting.

The compression member of box section with center rib allows the greatest practical section. If the thickness of web, flange and rib be kept uniform, it may be quite practical to develop a strong open section, with the center web as an I and the outer webs as channels.

Mr. J. W. Bowerman. — I have read Mr. Horton's paper on the compressive member with great interest, but lack of time prevents me from entering into as full a discussion of it as I should like. I think Mr. Horton's comparisons are well taken, although I do not entirely agree with him in some instances. The compressive member is usually one of the first serious problems confronting the young structural engineer, and apparently continues to be a problem of more or less uncertain solution throughout his career. I agree with Mr. Horton that a compressive member should be considered primarily as to its component parts, and am inclined to believe that failure to do so has been the cause of many failures in otherwise well-proportioned structures. Recently I was called upon to inspect and report on a small draw span that had collapsed. This was a pony truss draw, 170 ft. center to center of end bearings, 16-ft. roadway, with knee-braced top strut at center panel. The tower posts were made of two 6-in. 8-lb. channels, battened, and were 18 ft. 8 in. center to center of chords, or about 16 ft. outside of gussets. The strain in them was computed to be about 31 000 lb. when the draw was open; an increase of 4 000 lb. stress occasioned by small load on the draw at the time of swinging caused the failure of these posts, and hence the collapse of the bridge. The radius of gyration of a 6-in. 8-lb. channel with neutral axis perpendicular to the web at center, is approximately 2.34 in.; and a post constructed as these posts were of two such channels with the flanges turned in and $6\frac{5}{8}$ in. back to back, would have a radius of approximately 2.52 in. with neutral axis perpendicular to longitudinal axis and parallel with webs.

Under these conditions a post 18 ft. 8 in. in length, properly constructed, should be capable of supporting safely a load of about 9 800 lb. per sq. in. of section, or approximately 46 500 lb.; but in this instance there was an utter disregard of all accepted methods of lacing and battening. These posts were battened near the lower gusset plate, with 5-in. by $\frac{1}{4}$-in. by $6\frac{5}{8}$-in. batten plates, and four rivets to the plate, and at the top gusset with 3-in. by $\frac{1}{4}$-in. by $6\frac{5}{8}$-in. batten plates, and two rivets to the plate, and between at 4 ft. intervals on each flange side with 3 in. by $\frac{1}{4}$ in. by $6\frac{5}{8}$ in. batten plates, with two $\frac{5}{8}$-in. rivets to the plate. The radius of a 6-in. 8-lb. channel, parallel with the center line of web, is approximately 0.542 in.; if the post were computed on this basis (which of course would not be permissible in good practice) with accepted formulæ, allowing an average ultimate for medium steel, its ultimate capacity would be something like

6 000 lb. per sq. in. of section, or about 28 000 lb. Taking into consideration that the strain of 35 000 lb., at which these posts failed, was computed, together with the possible average range of ultimate strength of the material, it would appear that the battens on these posts had little effect other than to compel the failure of both members of the posts in the same direction. Had these posts been considered on the rule of thumb basis as free body girders, applying a load to the top of the channel web capable of producing a fiber stress in the channels at mid-length, equal to the difference between a unit stress of 16 000 lb. or 17 000 lb. per sq. in. and the allowed stress of 9 800 lb. per sq. in. it will be found that it would be necessary, in order to transfer the shear produced by such a load, to provide lacing bars about $1\frac{3}{4}$ in. by $\frac{1}{4}$ in. approximately 10 in. between rivet centers, and batten plates 7 in. by $6\frac{5}{8}$ in. by $\frac{1}{4}$ in. near the ends, using $\frac{1}{2}$-in. rivets.

A compressive member is as strong as its weakest portion only, and, although taken as a whole it may have several large radii of gyration, its component parts may have inherent defects, or it may be lacking in essential detail, not taken into account by the radii calculations.

There is little doubt that large compressive members of the size attempted in the Quebec bridge can be successfully built on our present knowledge of the subject; but close attention must be given to the several parts composing such a member to see that each part is properly proportioned to do its share of the work separately, as well as collectively. It must be apparent to the thinking engineer that the radius of gyration of a section as a whole cannot be taken as an absolute index to the strength of that section, but must be supplemented by other considerations.

OBITUARIES.

Oddgeir Stephensen.

Mr. Oddgeir Stephensen, electrical engineer with the Wagner Electric Manufacturing Company, died at St. Luke's Hospital, St. Louis, on Wednesday, February 1, 1911. At the time of his death, Mr. Stephensen was a member of the Engineers' Club of St. Louis, having been elected on May 3, 1905; he was also an associate member of the American Institute of Electrical Engineers and secretary of the St. Louis Section thereof.

Mr. Stephensen was born in Copenhagen, Denmark, on February 9, 1880. He graduated from the University of Copenhagen with the degree of B.A. in 1899, and for some time thereafter was employed as an apprentice with Ludwig Lund, of Copenhagen, a manufacturer of electrical machinery. In 1902 he came to the United States and entered the cable testing department of the Western Electric Company at Chicago, remaining with that company until November, 1904, when he took a position as field draftsman for the Missouri Pacific Railroad Company. Early in 1906 he was employed by the Wagner Electric Manufacturing Company of St. Louis as electrical engineer, and retained that position up to the time of his death, except for one year during which he was instructor in electrical engineering and graduate student at the University of Illinois.

Mr. Stephensen was actively connected with the work of local technical organizations and contributed occasionally to the programs. He represented the American Institute of Electrical Engineers at the Congress of the International Association for Testing Materials, held in Copenhagen in September, 1909. He was a young man of promise, and his untimely death is a source of deep regret to his many friends.

A. S. Langsdorf, *Chairman.*

Burton Irving Drisko.

Member of the Boston Society of Civil Engineers.

Burton Irving Drisko died suddenly at his home at Roxbury, Mass., on Sunday, January 8, 1911. He was born at Boston, Mass., on February 20, 1885, the son of Fred Herbert

Drisko, of the firm of O. H. Drisko & Son, contractors, and of Eva (Wass) Drisko. He prepared at the Roxbury Latin School of Boston, and took the Civil Engineering Course at the Sheffield Scientific School at Yale University, graduating in 1906.

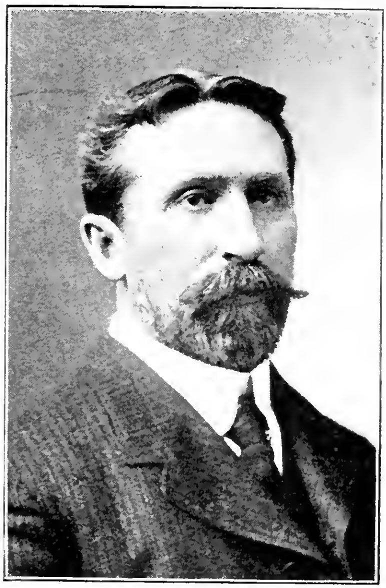
After graduating he took a position with the W. F. Kearns Construction Company of Boston, but on December 20, 1906, on account of ill health, he was forced to give up active work, which he could never resume. He spent the winter of 1906 in Southern California, returning home in May, 1907, and from that time until December, 1909, he was in Boston and in the mountains of New Hampshire. The winter of 1909 he spent in Orlando, Fla., returning in May, 1910, and was shortly thereafter taken with a severe heart complication from which he did not rally. He was a member of the Boston Society of Civil Engineers, joining December 19, 1906, and of the Boston Yale Club.

L. LEE STREET, *Committee.*

Louis Edwin Hawes.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

DIED JANUARY 29, 1911.



LOUIS EDWIN HAWES, son of Henry E. and Frances E. (Wesson) Hawes, was born in Springfield, Mass., January 27, 1860, his mother being a sister of the late Daniel B. Wesson, head of the world-famous manufacturers of the Smith & Wesson revolver.

His youth was passed in his native city, where at the age of fifteen years, as the eldest child of a widowed mother with six children, the stern duty of caring for and maintaining the family was suddenly thrust upon him. That this duty was faithfully

performed is attested by the filial affection and deep family devotion which characterized Mr. Hawes throughout life.

He studied at the Worcester, Mass., Polytechnic Institute, where he entered with zest into the sports of the day and was especially skilled in baseball and played the violin in the orchestra. Upon graduating in 1882, with the degree of B.S., he at once began active work in his chosen profession. In the summer of 1882 he was levelman and assistant engineer on the location survey for the Meriden & Cromwell Railroad, in Connecticut, and later in the year assistant engineer on water works construction at Northboro, Mass. During 1883 and 1884, he was assistant engineer on the Wakefield and Stoneham and North Attleboro, Mass., water works. In 1885 he was resident engineer on the Norwood, Mass., water works, and in 1886 served in the same capacity on the Juniper Hill reservoir, Rockland, Me., and was in charge of surveys for a sewerage system at Hyde Park, Mass.

In 1887 he was resident engineer on the construction of the Ayer, Mass., water works, and in 1888 assistant engineer on the Dover, N. H., water works, his work for the preceding five years having been under Mr. Percy M. Blake, C.E.

In 1889, Mr. Hawes began business for himself, opening an office at 75 State Street, Boston, but later removed to Tremont Street and continued in active practice as a civil and hydraulic engineer and as a contractor up to the time of his death, a period of twenty-two years. During this time he investigated, designed, reported upon or constructed new water systems or improved old ones in about forty towns and cities in New England and the West, and was frequently called as an expert in the appraisal of water plants, in legal controversies and in other matters involving hydraulic questions. Among the places where he has done work may be mentioned Avon, Needham, Provincetown, Lexington, Holden, Housatonic, Falmouth, Amesbury, Milford, Whitman, Edgartown and Marion, in Massachusetts; Middlebury, Vt.; Alton, Ill.; Independence and Newton, Kan. He designed and reported on a system of sewerage and sewage disposal for Wakefield, Mass., and in 1895 was chairman of the sewerage commission of that town. At the time of his death he was treasurer and manager of the Edgartown Water Company.

Mr. Hawes was a man of pleasing personality, unswerving integrity, strong religious conviction, and as an engineer thoroughly reliable, painstaking and observant of every detail. During a close professional association of over ten years the

writer never heard him utter a violent or unchaste remark or speak ill of anybody.

One of his contemporaries writes: "Mr. Hawes was a careful and painstaking engineer of ability and good judgment. Although modest and retiring in his manner, he gave to all matters entrusted to his attention a full consideration and the benfit of a well-balanced judgment. Whatever he did, he did well."

The chairman of the Holden, Mass., Water Commissioners, referring to the monthly estimates prepared by Mr. Hawes, wrote: "They are models of clearness and mathematical accuracy."

June 16, 1886, he married Miss Hattie M. Emerson, of Wakefield, Mass. The wife, a daughter and a son survive him.

Death was caused by apoplexy, and the interment is to be in Lakeside Cemetery in Wakefield.

Mr. Hawes was admitted to the New England Water Works Association December 12, 1888; to the Boston Society of Civil Engineers, June 20, 1894; and to the American Society of Civil Engineers, September 2, 1896.

George M. Warren,
E. Worthington,
Committee.

Leonard Parker Kinnicutt.

Member of the Boston Society of Civil Engineers.

Leonard Parker Kinnicutt was born at Worcester, May 22, 1854. He graduated in chemistry from the Massachusetts Institute of Technology in 1875. After graduation he studied for three years abroad at the universities of Heidelberg and Bonn and for a year at Johns Hopkins University under Professor Remsen. He was an instructor in chemistry at Harvard University from 1880 to 1883, and there received the degree of doctor of science, in 1882. In 1883 he was called to the Worcester Polytechnic Institute, where the rest of his life was spent, as assistant professor from 1883 to 1885, professor thereafter, and director of the Chemical Laboratory from 1890 to the date of his death, February 6, 1911. During this whole period he devoted himself to the study and teaching of the arts of sewage disposal and water purification. In 1903 he was appointed consulting chemist to the State Sewerage Commis-

sion of Connecticut and he has given expert testimony in many sanitary law suits.

Professor Kinnicutt was a fellow of the American Academy of Arts and Sciences, of the American Association for the Advancement of Science (serving as one of its vice-presidents in 1904), and of the English Chemical Society. He was a member of the American Chemical Society, the German Chemical Society, the Society of Chemical Industry, the Society of American Bacteriologists, the Boston Society of Civil Engineers, the New England Water Works Association; and an honorary member of the Society of Managers of Sewage Disposal Works of Great Britain.

Professor Kinnicutt was the leading sewage chemist of America; and his name was almost as well known and as highly honored in England and Germany as in the United States. He had an intimate and personal knowledge of men and conditions in all these countries and rendered a peculiar service in interpreting them to each other. A paper on "The Present Status of the Sewage Problem in England," in the twenty-eighth volume of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, and an address on "The Intermittent Filtration of Sewage as Practiced in America," delivered in England and published in the thirteenth volume of the *Journal of Preventive Medicine* may be recalled as particularly notable. He made contributions of the first importance to our knowledge of the processes of chemical precipitation and septic tank treatment, as in his two joint papers on "The Action of the Septic Tank on Acid Iron Sewage" in the third and fourth reports of the State Sewerage Commission of Connecticut. The results of his studies were finally summarized and brought together in a volume on "Sewage Disposal," of which he was the senior author and which came from the press only a few months before his death.

Dr. Kinnicutt was preëminently a teacher, for he had in high degree the power of unselfish service. For the quarter of a century in which he taught at the Worcester Polytechnic Institute, scores of young men went out every year with a knowledge of chemistry and a sound standard of values in science, derived from him; and with affection and gratitude for the man to whom they owed this. He possessed to an unusual extent ability to inspire enthusiasm, not only in his pupils, but also in all with whom he worked or came in contact. It was the same qualities which made Dr. Kinnicutt so intimate a figure in his city and among his professional associates and friends. He was endlessly

thorough and patient in his work, for his ideals of scientific honor and scientific accuracy were of the highest. Yet he had always strength for any new burden laid on his shoulders. He was tireless in well doing. To a multitude of philanthropic causes in Worcester he gave himself without stint; he found opportunity to bring comfort and cheer to the old and the ailing; and to younger colleagues his helpfulness and generosity knew no bounds. As one who knew him well has said, "Kindness and friendship such as his life exemplified could not further go. He was critical, yet just; fearless, yet considerate of others; honest to a fault; a hard worker; and, to a degree nowadays unusual, an accomplished and cultivated gentleman."

C.-E. A. Winslow,
Harrison P. Eddy,
Committee.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVI. JUNE, 1911. No. 6.

A NEW THEORY FOR THE DESIGN OF REINFORCED CONCRETE RESERVOIRS.

BY HIRAM B. ANDREWS.*

[Read before the Boston Society of Civil Engineers, December 21, 1910.]

THE theory which the writer is exploiting is derived by a process of evolution in the construction of several reservoirs in the past five years in which the writer has been directly interested either from an engineering or contracting standpoint or both. Until recently, and perhaps to some extent at the present time, the construction of reinforced concrete standpipes has been more or less experimental, possibly due to the fact that there have been few practical examples from which to derive knowledge. One of the first concrete reservoirs constructed was the one at Fort Revere, Mass., built by the War Department in 1903. This reservoir is described in the Journal of the New England Water Works Association of March, 1905.

The second of which we have record was built in Milford, Ohio, in 1904. This reservoir was designed and built by Mr. J. L. H. Barr, of Batavia, Ohio. It is 81 ft. high and 14 ft. diameter. For the lower 30 ft. the wall is 9 in. thick, for the next 25 ft., 7 in. thick, and the upper section of the wall is 5 in. thick. It is reinforced with steel tees according to the Weber system of chimney construction. The third reservoir of importance at this time, and which up to the past year was the tallest concrete reservoir in existence, was the one built at Attleboro, Mass., in

* Engineer for Simpson Brothers Corporation, Boston.

1905. This reservoir is 100 ft. in height and 50 ft. in diameter. The walls are 18 in. thick at the bottom and 8 in. thick at the top. It is reinforced with square twisted bars with a working stress of 13 500 lb. to the square inch at the bottom.

Up to the time that Simpson Brothers Corporation built the reinforced concrete reservoir at Waltham, in 1906, the three preceding examples were the only ones from which could be derived much information. This reservoir was designed by Bertram E. Brewer, city engineer, and J. R. Worcester was consulting engineer. Its dimensions were 100 ft. in diameter and 40 ft. in height, and it was calculated to contain a depth of 37 ft. of water. The dimension of the wall at the base was 20 in. and at the top 12 in. It was reinforced with round steel rods of medium quality, with a unit working stress at the bottom of 12 000 lb. per sq. in. The only connection that the writer had with this reservoir was as constructing engineer for the contractors, but in this capacity the problem of the methods of construction, the placing and securing of the reinforced steel, and the forms and the holding of forms in position devolved upon him, and the writer will say here that the methods adopted for carrying out such details as these will have much to do with the ultimate success of any work of this kind.

Between 1906 and 1909, Simpson Brothers Corporation built a few minor tanks and reservoirs, but none worthy of special mention, until the spring of 1909, when, in competition against steel, the contract for a reinforced concrete reservoir, to be constructed in Manchester, Mass., was awarded to them. This reservoir is 72 ft. in height and 50 ft. interior diameter, and contains, when full, about 1 050 000 gal. It was completed in July, 1909, and soon after its completion they were awarded a contract for a reservoir in Lisbon Falls, Me., 62 ft. in height and 50 ft. in diameter, containing 900 000 gal. During the past year they have built a reservoir at Rockland, Mass., 104 ft. in height and 46 ft. interior diameter, which, the writer thinks, with the exception of the one just completed in Mexico by Carl Leonhardt, engineer and contractor, contains the greatest depth of water of any ever built. The Mexico standpipe is 110 ft. in height. The Manchester, Lisbon Falls and Rockland reservoirs were all designed and constructed by the writer.

Another reservoir of note was that built by the state of Massachusetts at its state farm at Bridgewater in 1909, designed by A. J. Maynard, superintendent of construction, and on which the writer was consulting engineer. This reservoir is 30 ft. in

diameter and 78 ft. in height. The preceding are some of the principal examples of concrete reservoir construction in this country, excepting one recently constructed by the Aberthaw Construction Company, at Westerly, R. I., but the writer understands that Mr. Wason, who worked out the details of this, has also a record of others built here and abroad of more or less importance, of which he will tell you later.

Returning to review the principles governing the design of the concrete reservoirs enumerated, in circular water receptacles the water pressure at the base per square foot equals the product of the weight of water per cubic foot by the depth in feet. The tension in the wall per foot in height equals the product of the water pressure per square foot by the radius. For example, in the Manchester reservoir the water pressure per square foot at the base equals $62\frac{1}{2}$ by 72 equals 4 500 lb. per sq. ft. The tension in the wall for the first foot in height equals $62\frac{1}{2}$ by $71\frac{1}{2}$ by 25, equal to 113 300 lb. It has generally been assumed that this tension should be taken up entirely by steel reinforcement in the shape of horizontal steel rods bent to the radius of the reservoir and sufficiently lapped or mechanically attached to each other to develop the tensile strength when enveloped in concrete. It has been further assumed that a thickness of concrete sufficient to incase the steel reinforcement and to transmit the stress from one tension rod to another should be used. Empirical rules have been used for determining this thickness, relating only to obtaining the necessary bonding strength and a thickness of concrete supposedly enough to prevent seepage of water through the walls. No assumptions, to the writer's knowledge, have heretofore been made with the idea of utilizing the tensile strength of concrete prior to the construction of the reservoir at Rockland. The mixture of concrete that has generally been used in the past is one part of cement, two parts sand and four parts gravel or crushed stone, with the addition of hydrated lime or special compounds for densifiers, if I may use that term. As it is almost impossible to so thoroughly mix a 1:2:4 concrete either by hand or machine as to make it entirely impermeable to water, the walls and floor have been usually coated with a cement mortar or with some other waterproofing compound.

As there is a tendency for the diameter of a reservoir to increase after it is filled with water, due to the elasticity of the steel in tension, and as the base of the reservoir is practically rigid, due to its intimate contact with the foundation upon which

it rests, it has been deemed necessary to install some reinforcing material extending from the base up into the walls to take care of the bending moment and shear at the base. The writer does not know, nor has he been able to find any exact method of obtaining, the amount of steel required here, but he thinks that in most cases heretofore it has been underestimated.

As the several operations of building up forms, placing steel and concrete preclude making the concrete work continuous, it is advisable to make as short intervals as possible between successive layers of concrete, and where these joints occur to bond together the successive layers in the best possible manner. These instructions as outlined were followed out in the construction of the reservoirs at Waltham, Manchester and Lisbon Falls, except that the two latter reservoirs were made with a $1:1\frac{1}{2}:3$ mixture of concrete plus 5 per cent. hydrated lime. For the Manchester reservoir the thickness of the wall at the base is 20 in., and at the top 12 in. The steel is designed for a unit working stress of 12 000 lb. per sq. in. when the reservoir is full of water. At the base are installed rods which are embedded in the floor and turned up into the walls. These rods are 1 in. in diameter and are laid 12 in. on centers and extend into the wall about 4 ft. 6 in. The floor was finished with 1 in. granolithic, and the walls were plastered with two coats, making about 1 in. in thickness of 1:1 cement mortar. But after the filling of the reservoir various features were observed which showed that some improvement might be made in the design of future work.

We say design, and emphasize this word, as the workmanship on this reservoir was done with the utmost care and the material was of the best quality, and we do not see where it could be materially improved in this respect.

There developed at several of the horizontal joints — and especially at the three lower joints — between day's works, some seepage of water, which in three places increased to positive leaks. The seepage, however, at the upper joints gradually stopped, presumably due to the filling of the pores by hydrated lime. We at first saw no reason why any leakage should develop. We had supposed that the concrete was rich enough, that the inside coating of 1:1 plaster, put on in such a manner as to make a double lap over the joints, and the care taken in grooving and grouting the joints between day's works, were sufficient to make the reservoir absolutely tight, and when we found that a little leakage did occur after taking all these precautions, we naturally began an investigation to determine the reason or

reasons therefor, and to obtain for future work some protection against it. Upon examination of the reservoir after it was emptied, we found that there were horizontal cracks at the joints mentioned, about 30 ft. long, and extending through the wall, also that there were vertical cracks in the plastering extending upward for 20 ft. or so, and furthermore, that there were checks in the plastering from which the water oozed back into the reservoir after it was emptied.

From these observations we made the following deductions, that there was not enough vertical steel properly distributed to fully distribute the bending moment and shearing stress between the rigid base and the walls, and that the lack of this probably was the cause of the horizontal cracks. Second, that the ultimate strength of the concrete was probably exceeded when the reservoir was filled with water, thus producing the vertical cracks, and that these vertical cracks allowed the water to permeate into the walls and through them to the lines of least resistance, which would be the horizontal joints. Third, that the addition of a rich plaster coat with a more or less permeable concrete back of it was useless, as the usual crazing and the vertical cracking which would occur due to the tension would also allow the percolation of water through it.

This second deduction is the basis of this paper. From tests which have been made on concrete beams, it has been found that microscopic cracks have developed in the concrete on the tension side when the steel reinforcement was stressed to 4 000 or 5 000 lb. per sq. in., or perhaps less; that these cracks gradually widened until they were finally visible. It is presumable that these cracks began when the ultimate strength of the concrete in tension was reached, and at a time that the unit stress in the steel was approximately ten times that in the concrete. These microscopic cracks were made visible by the application of water, and water lines following them could be seen. If these cracks developed in beams when the stress in the steel was only 5 000 lb. or thereabouts, sufficient to admit water, why should they not develop in reservoir walls when the steel was stressed to the same point? And furthermore, if the walls were made so thin that they took little of the tensile stress, it being all thrown in the steel, at 12 000 or 16 000 lb. per sq. in. or at any intermediate working value between these, why would not vertical cracks show in the walls, and permit water to seep into the walls?

One of the first requisitions in a concrete reservoir is to make it water-tight. The writer did not see how he could be sure

that it would be water-tight if he so designed it; that the cracks in the concrete were predetermined. The only remedy seemed to be to make the walls so thick, and of such a composition, that their tensile strength would never be exceeded.

Having this in mind when we came to the design of the reservoir for Rockland, Mass., and after consultation with Mr. J. R. Worcester and Mr. Sanford E. Thompson to obtain their ideas and approval of an innovation in the construction, we decided to use an especially rich mixture of concrete, a thickness of wall which would insure that the ultimate tensile strength of the concrete would not be reached when the reservoir was filled, to use an increased amount of vertical reinforcement especially between the base and the walls, and to install a steel dam at each horizontal joint between each day's work to prevent any direct seepage of water through the joint, provided it entered it. The hydrated lime was omitted, as we considered the proposed density of the concrete did not require it for unpermeability, and also that where it had been used previously it had caused an unsightly efflorescence on the wall wherever there had been seepage. The plastering was omitted as we considered that any rigid coating upon this mixture of concrete was unnecessary; but instead, we applied three coats of soap and alum solution, commonly known as Sylvester Compound, to fill pinholes due to air bubbles, etc.

The writer does not know that this was of any practical use, but it was a precaution which we took. The thickness of wall at the base was determined as follows.

We assumed that a 1:1:2 concrete in tension was good for approximately 400 lb. per sq. in., that the working stress in the steel, if by any chance the full tension was thrown upon it, would be 16 000 lb. per sq. in., and that the ratio of moduli of elasticity between steel and concrete was 10, so that if the concrete was stressed to 300 lb. per sq. in. the steel would be stressed to 3 000. The tension at the base of a standpipe 46 ft. in diameter and 104 ft. in height when filled with water would be $62\frac{1}{2}$ by 104 by 23, equal to 149 500 lb. per ft. in height. At 16 000 lb. per sq. in. this would require 9.35 sq. in. of steel per foot in height at the base, which was the section used. We made the thickness of wall 36 in. at the base, the sectional area of concrete being (36 by 12) — 9.35, equal to 422.65 sq. in.

Let X equal unit stress in concrete, and $10X$ the unit stress in steel, then $422.65X + 9.35\ (10X) = 149\,500$ lb.; solving, X equals 290 lb., which was considerably lower than the ultimate

strength of 400 lb. which we assumed. As we could find no tests of concrete in tension, we decided to have some made of large-sized briquettes at the Watertown Arsenal. We thereupon ordered our superintendent of construction on the Rockland job to make up some briquettes of special design, having a minimum cross section 4 in. square. These briquettes were made of the same material and in the same manner as the concrete was made for our regular work, the 1:1:2 concrete being taken from the mixture while the regular work was going on.

We also made twelve 6-in. cubes for testing the compressive strength of the same concretes. The test pieces were made between August 1 and September 8, and the tests were made sixty days thereafter, between October 29 and November 7. The average tensile strength of the 1:2:4 concrete was 113 lb. per sq. in., of the 1:1½:3, 202 lb. per sq. in., and of the 1:1:2, 281 lb. per sq. in., there being no great variation from this average in any one of the tests. The average compressive strength of the cubes were as follows: 1:2:4, 2 280 lb. per sq. in.; 1:1½:3, 3 657; 1:1:2, 4 845. Upon examination of the fractured tension pieces it was evident that the increasing ratio of tensile strength when the richness of mixture was increased was due to the larger amount of mortar in cross section in the 1:1:2 concrete. As this concrete showed very few stones at the fractured section, while the 1:2:4 concrete showed a large number, it was plain that the adhesiveness of the mortar to the stones was not equal to the cohesiveness of the mortar.

In regard to the tensile specimens we quote from the paper made by the engineer in charge of the test.

"No change in the specimens was observed until rupture occurred. This took place quietly on a plane approximately perpendicular to the axis of the specimens and followed the surface of the gravel in nearly all cases."

From the results obtained we checked our previous assumptions. The average tensile strength of 1:1:2 specimens was 281 lb. per sq. in. We assumed that in large-sized sections this possibly would be increased 25 per cent., and that if these sections were reinforced by steel, that a further increase in strength of at least 10 per cent. might be expected.

Our first assumption was made by reason of the fact that large-sized specimens in compression usually showed about this percentage of increase over small ones, and our later assumption was based on the following theory.

If an unreinforced section is subjected to tension, when

its ultimate strength is approached a crack will develop at the line of least resistance, and the fracture will always occur at this point. If the section is reinforced, the ultimate fracture will not necessarily be at the point where the first crack developed, as the strain would be distributed nearly equally over the entire section by the reinforcing steel, and the fracture would take place at a plane in which was located the resultant of a number of weaker areas of concrete.

Perhaps the writer has not made his theory in regard to this entirely clear, and would like to have it discussed later.

We, however, assumed our original figure of 281 lb. increased by first 25 per cent. and then 10 per cent., making a tensile strength of 386 lb. per sq. in., which was probably nearly its actual value in the wall. It has been previously shown that the maximum tensile stress in the concrete would be 274 lb. per sq. in., and the corresponding tensile strength in the steel 2 740 lb., so that there would be a margin of about 40 per cent. left for a factor of safety in the concrete without approaching the limitation on the steel. If, however, our assumptions had been wrong and no tensile stress whatever was taken by the concrete, which would be unreasonable, then we still had steel enough to take all the stress at 16 000 lb. per sq. in. or its ordinary working value.

Applying this same line of reasoning to the Manchester reservoir, it is found that the tension at the base if divided proportionately between the steel and the concrete would be approximately 3 500 and 350 lb. per sq. in. respectively. We have assumed that the ultimate tensile strength of the $1:1\frac{1}{2}:3$ concrete would be 202+25 per cent.+10 per cent., equal to 278 lb. per sq. in., so that it is evident that the tensile strength of the concrete of the reservoir wall is exceeded, and that the vertical cracks developed might be expected.

We further find that at a point 25 ft. up, the tensile strength of the concrete plus the tensile stress in the steel just equals the stress due to water pressure at this point, and it was at about this place that the vertical cracks in the plastering disappeared.

There was never any trouble with the Lisbon Falls reservoir. A few damp spots appeared at first on the surface, but these soon disappeared. This reservoir is 62 ft. high and 50 ft. diameter, and the walls are 20 in. thick at the base; $1:1\frac{1}{2}:3$ concrete was used and a 12 000 lb. per sq. in. working stress on the steel was assumed. The assumptions previously made would show a stress in the concrete of 235 lb. per sq. in. and 2 350 lb. per sq. in. in the steel. This stress in the concrete being less than its

ultimate strength, we did not expect to find any vertical cracks with a resultant leakage.

The reservoir at Bridgewater is 78 ft. in height and 38 ft. diameter, and the walls at the base are 20 in. thick. This reservoir has never shown a particle of leakage. The stresses developed in concrete and steel are about 240 lb. and 2 400 lb. per sq. in. respectively. As an example of comparatively thin walls with a resultant leakage we will cite the reservoir at Attleboro, Mass. This reservoir is 100 ft. in height, 50 ft. in diameter, and the walls at the base are only 18 in. thick; 1 : 2 : 4 concrete was used in its construction; 13 500 lb. per sq. in. was the working stress adopted for the steel. From our previous examples, the stress in concrete and steel would be about 500 and 5 000 lb. per sq. in., but the stress in the concrete so far exceeded its ultimate strength that numerous vertical tension cracks must have developed to a considerable height. In this case presumably the relative values of concrete and steel would not hold, but a stress of steel must have been developed to somewhere near the working value assumed. Several attempts have been made to make this reservoir water-tight, but each refilling has always resulted in leaks. The cracks in the concrete have probably been reproduced in any surface coating which has been applied.

A reservoir 70 ft. diameter and 22 ft. in height containing 20 ft. of water was constructed in Bondsville in 1908. The walls were 12 in. thick, and composed of $1:2\frac{1}{2}:4\frac{1}{2}$ concrete with 5 per cent. hydrated lime added to the cement. The unit stress in the steel is 14 000 lb., and in the concrete at the base 260 lb. per sq. in. The ultimate strength of a $1:2\frac{1}{2}:4\frac{1}{2}$ concrete in tension may be assumed to be 100 + 25 per cent. + 10 per cent = 137 lb. per sq. in. Therefore the actual strength of the concrete was considerably exceeded.

The owners expected an absolutely tight structure. When it was filled, considerable leakage developed at the joints, although there were no actual streams or jets of water coming through. The writer is informed that upon examination many vertical cracks were found in the concrete walls in the interior.

The Waterproofing Company were employed to put on their hydrolithic coating, and they put it on under a guaranty that the reservoir would be tight. After this work was done, and the reservoir filled, the same cracks were reproduced in the hydrolithic coating, and the writer understands that these cracks have been cut out and filled twice since the original coating was put on.

It is hard to say just what factor of safety against bursting there is in a concrete reservoir. We are, however, working on the side of safety in making the walls thick instead of thin. There is on record the case of the complete failure of a concrete reservoir in New South Wales described in the *Engineering News* of June 16, 1910. This reservoir was 40 ft. high and 40 ft. interior diameter, capacity 314 000 gal. The walls were 10½ in. thick at the bottom and 4½ in. thick at the top. It was built of a 1:2:2 concrete. The reinforcing rods were round rods with a working stress of 16 000 lb. per sq. in. These rods were laid in one vertical plane.

We will quote from the article giving the appearance of the reservoir after failure. The article is too lengthy to quote entirely, but can be read in the *Engineering News*.

"Appearance of Reservoir after Failure.

"From a careful examination made immediately after the failure, it would appear that the reservoir failed all round simultaneously, or almost so, and that the upper half then fell upon the foundation and crumpled over. A portion of the upper section of the shell, about 18 ft. 6 in. in height, was found standing nearly vertical upon the foundation, but of the lower half of the reservoir only a few small sections remained, showing the full thickness of the concrete with the rods embedded therein, as constructed. Practically the whole of the lower portion of the shell had split in halves along the line of the reinforcing rods, and the ground was strewn with pieces of concrete of the half thickness of the shell, and up to about 2 ft. by 2 ft. in dimensions. The rods, which were in most instances lying free of any concrete, had been thrown with force against trees, round which they were bent, or against the sides (6 ft. to 8 ft. high) of the old quarry in which the reservoir was built.

"The largest piece of the bottom half which had not been entirely destroyed measured about 10 ft. by 8 ft., and was lying against the side of the excavation opposite to the 18 ft. 6 in. vertical upper section. This portion had been turned upside down, and the inside face was lying against the bank, thus demonstrating the great force with which it had been thrown out at the time of failure."

In view of the experience the writer has had, and from all the outside information he has gained, he would certainly recommend a careful consideration of the subject before using very thin walls on concrete reservoirs of considerable height.

DISCUSSION.

Mr. Raymond C. Allen. — There is one thing which I think is rather interesting in the manner in which the leaks developed in that standpipe. I think Mr. Andrews' theory of design is good, in that there will certainly be less failure for leakage, but it does not explain why, in Manchester, the standpipe only leaks on a stretch about twenty feet on the easterly and southeasterly side, where the maximum temperature stresses occur from the sun, while in every other place in the standpipe there was not a drop of leakage. I think that had something to do with the stressing of the concrete there.

On the inside of the standpipe and on the northerly and more protected sides, where the temperature, I presume, is much more uniform, the checking effect was much less.

I think Mr. Andrews has covered the leakage pretty well. As nearly as I could estimate, the leakage between the first and third joints was at a maximum of 15 000 gal. in twenty-four hours. That was the most serious leak we had. The leaks at other times have been matters of perhaps a few hundred gallons a day. At the present time not more than 10 or 15 gal. a day is seeping out in a space 8 ft. long and 6 in. wide at the very base.

Perhaps I might say a word as to some of the estimates received when we put in this reservoir. We planned a reservoir 60 ft. in diameter and 70 ft. high, and on that basis we procured bids for a steel standpipe or reservoir and one of reinforced concrete. The figures on steel ranged from a minimum of $24 000 to a maximum of $35 500, an average of about $29 000. The reinforced concrete ranged from $33 290 to $43 000, taking the average price bid by the steel firms, which, in my opinion, is somewhere nearly right, because the site upon which the reservoir was placed was very inaccessible — and the weight — 300 tons — and also the value of the concrete, $33,290, and its weight, — rising 3 000 tons, — and adding the extra cost of getting the material on to the hill and into place, brings the cost about on a parity. Those figures would compare equally well for a 50-ft. standpipe, because the bids received before it was decided to build a standpipe of smaller diameter were about in the proportion of the figures I have given you.

The Chairman. — I trust Mr. Allen is satisfied with what he has and would not go back to steel?

Mr. Allen. — I think we are satisfied, Mr. President.

Mr. L. C. Wason. — When a discussion on standpipes was first mentioned to me I asked the American Society of Civil

Engineers to compile a list of all the reinforced concrete standpipes built in this country and abroad as found in print. To that list I have added nine New England standpipes, and one in New South Wales. It is interesting to know that the first one erected in this country was that at Little Falls, N. J., in 1899, although it is concealed from view inside the filter plant which it serves; and to date there have been 52 built in this country and abroad.

You will note that there are 13 New England tanks in this list, and also the fact that no tank has been built outside of New England with a capacity larger than one-half million gallons; while inside there have been six of larger capacity, of which three are over one million gallons. This would indicate that local engineers and water companies have more faith in this type of construction than those in any other part of the world.

The company with which I am associated has built two large standpipes, and a tank, the smaller 40 ft. in diameter and 70 ft. high at Westerly, R. I., and the larger at Attleboro, Mass., 50 ft. in diameter and 100 ft. high to water level.

The Attleboro standpipe was designed on the basis that the hoops take the entire load with a unit stress in the steel of 13 500 lb. per sq. in. In order not to have the bars too close together, $1\frac{1}{2}$-in. diameter bars were used in two rows from the bottom of the standpipe to a height of 61 ft. From 61 ft. to 81 ft. a single row of $1\frac{1}{2}$-in. diameter bars was used. From 81 ft. to 100 ft. the bars were $1\frac{1}{8}$-in. diameter. In the upper 15 ft. of the height the section of steel was kept a constant, although the hoop stresses from the water were constantly diminishing to the top. This was done to provide for possible stresses caused by the formation of ice in the standpipe. In actual practice it was found that, owing to the frequent fluctuation of the surface of the water, ice did not form solidly over the whole water surface of the tank, so that pressure on walls never really occurred.

The walls of the standpipe started with a thickness of 18 in. at the bottom, and tapered to a thickness of 8 in. at the top.

In order to space the reinforcing bars the exact distance apart, 4-in. channels with a $\frac{3}{8}$-in. hole through both flanges were used. The holes in these channels were punched so as to give the exact spacing required for the hoops. The channels were set upright at intervals of about 15 ft. center to center, a $\frac{1}{4}$-in. rod was passed through the holes, and the hoops were rested directly on the ends of these $\frac{1}{4}$-in. rods, which were then

bent up to secure the hoop firmly. From the height of 61 ft. to the top of the standpipe where there was but a single row of hoops, 3-in. channels were used for spacers instead of the 4 in. The floor of the standpipe was 12 in. thick and met the wall with a curve whose radius was 5 ft.

The top surface of the floor was reinforced with $\frac{1}{4}$ in. square twisted bars 6 in. on centers each way. These bars were carried well up the curved corner, and into the wall of the standpipe; $\frac{5}{8}$ in. square twisted bars were also placed radially at intervals of about 3 ft. around the circumference of the standpipe, their ends projecting up into the wall for a height of 10 ft.

The foundation consisted of a slab about 18 in. thick. Immediately under the walls of the standpipe, however, the depth of this slab was increased to 4 ft. for a width of 5 ft. A concrete curb 3 ft. high and 12 in. thick with a curved top was built around the outside of the standpipe at the bottom, but was not monolithic with it.

On one side a gate-house was erected enclosing the various valves and giving access through a passage covered by a balanced manhole cover to the interior of the standpipe.

The roof was a Guastavino tile dome in which were suitable means of ventilation.

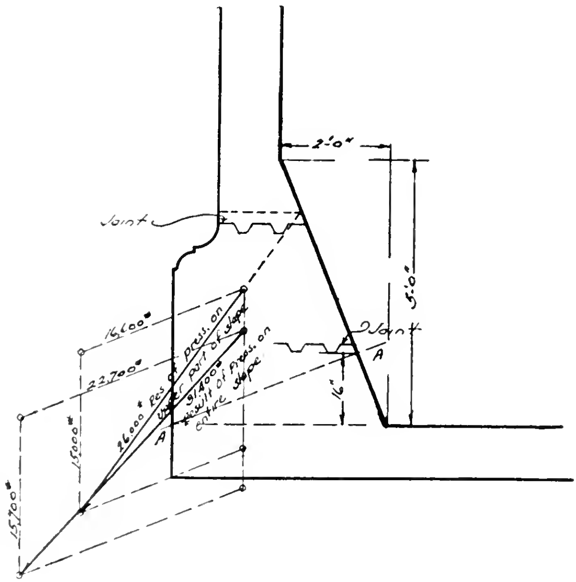
At the high-water line a series of rectangular slots were left in the walls whose total area was greater than the area of the inlet pipe. These holes effectually prevented the water reaching a higher level than the one for which the standpipe was designed.

The method used in splicing the ends of the bars together may be of interest. These bars were obtained long enough so that three would reach entirely around the circumference, with a lap of 40 diameters at each joint. Two wire rope clips were then used at each splice to insure the bars being held firmly together. It was found by actual test at the Watertown Arsenal that these clips alone were sufficient to secure the full working stress of the bare bars, so that any additional bonding strength from the concrete was added to the factor of safety. These splices were staggered so that one in eleven loops came in the same vertical plane.

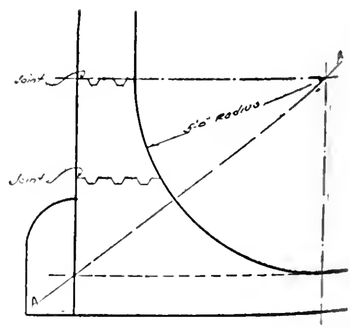
From the experience with this standpipe, and with that at Westerly later, I believe that the addition of considerable vertical reinforcement in the lower 8 or 10 ft. of the standpipe wall, the ends of which are turned out and bonded well into the floor, would assist very materially, and perhaps entirely obviate the formation of a horizontal crack in the lower few feet of a

standpipe. It is obvious that under water pressure the walls, owing to the deformation of the steel, must increase in circumference, and the entire tank increase in diameter in proportion. At the bottom of the standpipe, however, owing to the rigid connection of the wall with the floor, this increase in diameter cannot take place. This rigidity extends a short distance upward to the point where compression on floor changes to tension in wall. At the finish of a day's work near bottom of tank at or quite close to the plane of weakness above indicated there may be a direct movement outward of the wall above, relatively to that below, the joint when under pressure. When the pressure is relieved the elasticity of the hoops would tend to draw the wall back to its original position.

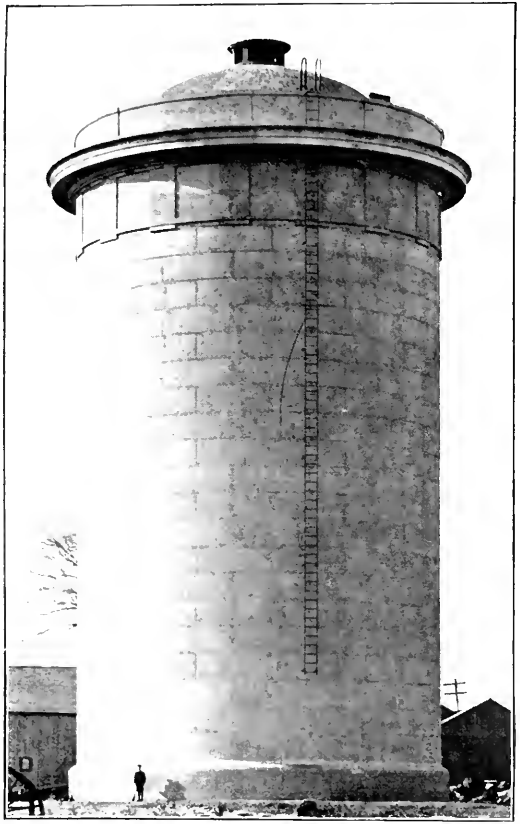
It is apparent then that unless precautions are taken, either by the use of very low stresses in the hoops, or by the addition of vertical steel bars, there may be a distinct movement back and forth on some joint in the standpipe. That this movement is present is further indicated by the fact that when a standpipe has been kept full of water for some time, the leakage through these joints almost entirely disappears, but on emptying the standpipe and refilling it the little dams formed have apparently been broken down, as the leakage again occurs as vigorously as at first.



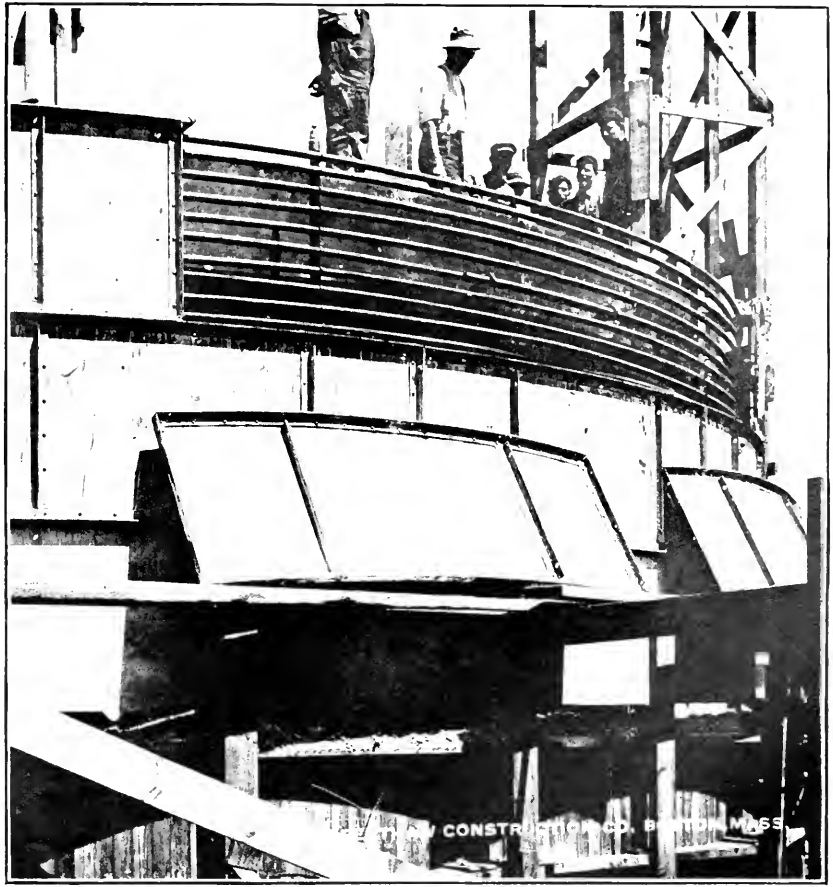
STANDPIPE AT WESTERLY. R. I.



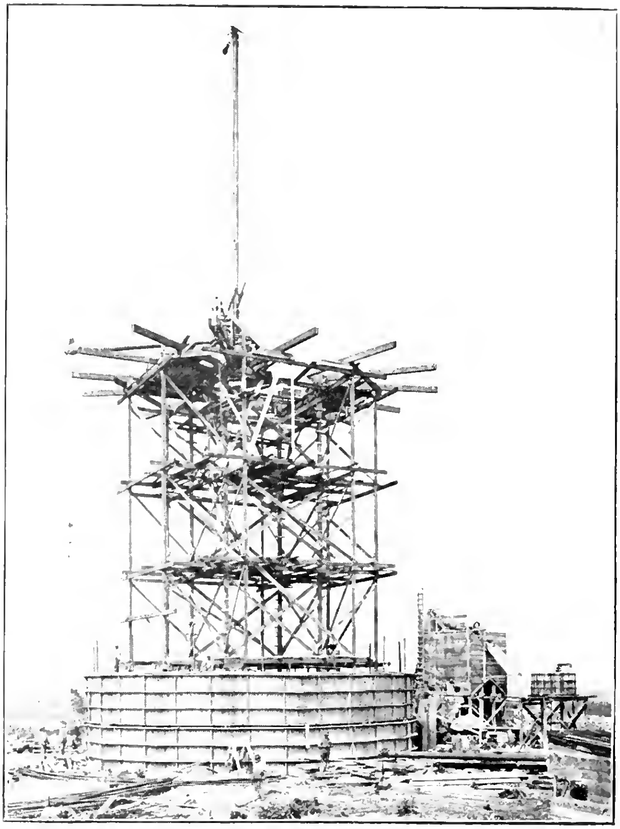
STANDPIPE AT ATTLEBORO. MASS



Standpipe at Westerly, R. I.



Steel Forms for Concrete Standpipe at Westerly, R. I.



Tower in Standpipe at Attleboro, Mass.

Working Stage in Interior of Standpipe at Westerly, R. I.

In the Westerly standpipe we endeavored to take care of this by increasing the amount of steel. At the lowest foot the stress was 6 000 lb. per sq. in. This stress was increased 1 000 lb. for each foot in height until we reached a maximum stress of about 12 500 lb. per sq. in. No vertical steel, however, was used, and on filling the standpipe we found with the maximum head of water that a small line of dampness occurred in a horizontal joint about $3\frac{1}{2}$ ft. above the floor of the tank. This damp place was nearly 30 ft. long.

By reference to the cut showing the section of the base in these two standpipes will be seen the position of what I call the critical joint. On the section of the Westerly standpipe a diagram is shown indicating the forces existing from the weight of the wall and the outward pressure of water on the sloping corner. The resultant of these two forces is shown. Projecting this resultant backward to the inside face of the wall the point is found where compression probably changes to tension. This is the critical point. It also comes very close to the joint where the second day's work left off. This is the joint that leaks. After the tank had been filled three weeks the leakage was just sufficient to dampen the surface, but did not run down. If this point in a standpipe can be taken care of, it is my belief that a standpipe can be made bottle tight.

In these two standpipes quite different methods were used in erection. At Attleboro a large tower (see cut) consisting of 8 in. by 8 in. hard pine timbers properly braced was erected. On the top of this tower were placed two bull-wheel derricks. Concrete was handled in a bottom dump bucket swung to the position desired by the derricks, dumped in boxes and shoveled into the wall. The forms were of wood in sections about 7 ft. high of such sizes that they could be handled easily by the derricks, or if necessary by the unaided power of the men.

At the Westerly standpipe (see cut) the plant consisted of a simple concrete mixer fed by wheelbarrows. The mixed concrete was delivered to an ordinary elevator, hoisted to a hopper erected on the elevator tower where it was dumped, from which it was fed into wheelbarrows and shoveled into place. The forms were made from $\frac{1}{8}$ in. steel plates riveted to $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. angle irons which were bent to the proper curve. These forms were made up by a boiler maker. They were about 3 ft. high and two sets were used, so that the bottom one could be taken off and re-erected, enabling us to pour 3 ft. of concrete a day. The lump sum price of $1 000 was paid for

these steel forms. The saving in labor from their use was sufficient to more than pay for the cost of the forms themselves over what was estimated for the use of wooden forms. They gave a very satisfactory finish to the wall, as the cut of the finished standpipe will indicate. No pointing was done.

A very light platform was used for a working stage in the interior of the standpipe. This is shown in the accompanying cut. Wooden posts 3 in. by 4 in. were carried up, one near the wall and one near the interior, at 8 points to support this stage. The stage consisted of 2-in. planks resting on channel irons which were bent carefully to a circle and cross braced. Two channel irons were carried across the center of tank from side to side on one diameter and two others an another diameter at right angles. These not only served to stiffen the staging but gave a means of access to the center of the standpipe so that a plumb bob could at all times be lowered and any deviations from a true circle be detected. The wooden posts were carried up ahead of the work. Cross bars were put across the top of them, and then eight differential pulleys were used to lift the staging quickly to any point desired. Immediately this point was reached cross bars were nailed from post to post under the staging, holding it securely in place.

As on the preceding standpipe, a Guastavino tile dome was used for a roof.

In addition to the leak near the bottom of this standpipe above mentioned, three spots, and only three, appeared which leaked; one very close to the floor, caused by a breakdown in the mixer, resulting in a delay of an hour or so between batches of concrete, thus breaking the bond and destroying the monolithicity of the floor. There was another one about 23 ft. up, and one about 40 ft. These were grouted under high pressure and stopped. The worst of the three leaks before they were grouted dripped one drop in six seconds. Very great caution was exercised in finishing the joint between the days' work. Two men were kept on into the night after concrete was placed to scrub the top surface of concrete very carefully with brushes and water to get the laitance off, and also to wash the surface of all stone showing on top as clean as it was before being mixed, because cement bonds very well to clean aggregates; but it does not bond well to old cement. Roughing strips were put in the wall to form a groove. These were also removed by the men in the evening. Before concrete was placed the following day the surface was thoroughly washed with water, then coated

with neat cement, which was rubbed in with a brush, and the grooves formed by the roughing strips were filled with neat cement.

The following list of structures is supposed to be a complete list of all so far built. Where the word "standpipe" is used, it is used to mean a receptable primarily used in connection with a water-works system. Where the word "tank" is used, it is understood to mean a receptacle which is not primarily for water works, and may be made to contain either pure or impure water. These two words are arbitrarily used with this understanding in this tabulation. Some of the references refer to "tanks" without stating the number. In the table only two were assumed to have been built.

1897. STANDPIPE. GERMANY. 132 000 GALLONS.

No description given.

"Das Wasserwerk der Stadt Calbe," by Paul Möller.

Zeitschrift des Vereines Deutscher Ingenieure, Vol. 41, p. 301 (March 13, 1897).

1899. STANDPIPE. LITTLE FALLS, N. J. 25 260 GALLONS.

10 ft. diam., 43 ft. high, walls 15 in. thick at bottom and 10 in. at top.

Transactions American Society of Civil Engineers, by Wm. B. Fuller, Vol. 50, p. 454.

Discussion of paper 954, June, 1905.

See also Transactions American Society of Civil Engineers, Vol. 54, Part E, pp. 433-34.

1902. STANDPIPE. AMSTERDAM, HOLLAND.

"Bauwerke," *Beton und Eisen*, Vols. 1 and 2, p. 9.

1903. STANDPIPE. MILFORD, OHIO. 93 000 GALLONS.

81 ft. high, 15½ ft. outside diam., walls 5 in. to 9 in. thick.

Engineering News, Vol. 51, p. 184 (February 25, 1904).

Engineering Record, Vol. 49, p. 382 (March 26, 1904).

Municipal Journal and Engineer, Vol. 21, p. 543.

Transactions American Society of Civil Engineers, Vol. 54, Part E, p. 433.

STANDPIPE. FORT REVERE, HULL, MASS. 118 000 GALLONS.

Octagonal tower, 33 ft. diam. at base, 84 ft. high; tank, 20 ft. inside diam., 50 ft. high; wall 6 in. thick at base, 3 in. at top.

"Description Concrete Steel Water Tower and Standpipe, Fort Revere, Hull, Mass.," by Leonard S. Doten.

Journal of the New England Water Works Association, Vol. 19, p. 33 (March, 1905).

Abstract *Engineering News*, Vol. 52, p. 596 (December 29, 1904).

Abstract *Engineering Record*, Vol. 48, p. 218 (August 22, 1903).

Municipal Journal and Engineer, Vol. 21, p. 543 (December 5, 1906).

Transactions American Society of Civil Engineers, Vol 54, Part E, p. 433, Edwin Thacher.
International Engineering Congress 1905, paper 70.
Proceedings of Illinois Society of Engineers and Surveyors, Vol. 22, p. 33–44 (1907), by Charles B. Burdick.
Cement and Engineering News, Vol. 19, p. 138 (June, 1907).

STANDPIPE. LEIBNITZ, GERMANY. 95 000 GALLONS.
Tank stands on high reinforced concrete support. It is 13 ft. 2 in. in diam., and 9 ft. 10 in. deep.
Beton und Eisen, Vols. 1 and 2, p. 311.

2 STANDPIPES. EKATÉRINOSLAV, RUSSIA. 52 800 GALLONS AND 26 400 GALLONS.
Two tanks, one above the other, 32 ft. 10 in. diam. The larger one, 49 ft. from the ground; the second, 97 ft. from the ground.
Beton und Eisen, Vol. 3, p. 152 (June, 1904).

TANK. 64 250 GALLONS.
Supporting tower of pure concrete 36 ft. 1 in. high.
Zeitschrift des Vereines Deutscher Ingenieure, Vol. 49, p. 1257 (July 29, 1905).

1904. STANDPIPE. ATTLEBORO, MASS. 1 500 000 GALLONS.
50 ft. diam., 100 ft. depth of water; total height 118 ft.; walls 18 in. thick at base, 8 in. at top.
Engineering News, Vol. 57, p. 212 (February 21, 1907). Rein. conc. Attleboro, Mass.
Engineering News, editorial, same issue.
" Present Condition of Attleboro Standpipe."
Engineering News, Vol. 62, p. 199 (August 19, 1909).
Editorial, same issue.
Engineering News (letter), Vol. 62, p. 230 (August 26, 1909).
" Concrete Construction, Methods and Cost," p. 609, by Halbert P. Gillette and Charles S. Hill. New York, 1908.
" Reinforced Concrete for Standpipes and Tanks," by Charles B. Burdick.
Proceedings Illinois Society of Engineers and Surveyors, Vol. 22, pp. 33 and 44.
Cement and Engineering News, Vol. 19, p. 138 (June, 1907).

TANK. ENGLAND. 345 000 GALLONS.
70 ft. diam., tower 60 ft. high.
Transactions American Society of Civil Engineers, Vol. 54, Part E, p. 548, by R. G. Gifford Read.

STANDPIPE. PARIS, FRANCE. 110 000 GALLONS.
Octagonal tower 28 ft. 6 in. in diam.; tank is 22 ft. deep, 39 ft. in diam.
" Concrete Water-Tower at La Villette, Paris," by Max de Nansouty.
Minutes of Proceedings of the Institution of Civil Engineers, Vol 159, p. 436 (1904–5). (Part 1.)

2 STANDPIPES. FRANCE. 118 500 GALLONS.
12 ft. 7 in. diam., 45 ft. high.
"Château d'Eau de l'Intercommunale du Centre," by O. Amiras.
Beton und Eisen, Vol. 5, p. 198 (August, 1906).

TANK. BELGIUM. 18 700 GALLONS.
Tank is divided into two pipes, each having a diam. of 9 ft. 10 in. and a water height of 16 ft. 5 in.
"Der Wasserturm in Forest (Belgien)," by O. Amiras.
Beton und Eisen, Vol. 4, p. 26 (February, 1905).
"Le Château d'Eau de Forest."
Le Ciment, Vol. 10, p. 29 (February, 1905).

TANK. GERMANY CAPACITY NOT GIVEN.
"Ein Wasserturm in Eisenbeton für das Königl. Gestüt Rohrenfeld in Bayern."
Deutsche Bauzeitung, Vol. 39, Supplement, p. 16 (1905).

1905. STANDPIPE. ITALY. 13 200 GALLONS.
20 ft. 4 in. high, diam. of outer shell 15 ft. 2 in.
Engineering Record, Vol. 53, p. 371 (March 17, 1906).
Beton und Eisen, Vol. 4, p. 296 (December, 1905).

TANK. GERMANY. 137 200 GALLONS.
34 ft. 6 in. diam., 20 ft. high.
Beton und Eisen, Vol. 5, p. 134 (May, 1906).

2 TANKS. HAMPTON, VA. 66 000 GALLONS.
26 ft. 6 in. diam., 16 ft. high.; walls 12 in. thick.
Transactions American Society of Civil Engineers, Vol. 54, Part E, p. 433, by Edwin Thacher.

1906. STANDPIPE. ANAHEIM, CAL. 172 000 GALLONS.
30 ft. 3 in. diam., clear interior depth 32 ft.; rests on twelve reinforced concrete columns 60 ft. long.
Engineering Record, Vol. 56, p. 203 (August 24, 1907).
"Concrete Water Tank," by Edward P. Bailey.
Municipal Journal and Engineer, Vol. 28, pp. 366, 527 (March 9, 1910; April 13, 1910).

TANK. KANSAS CITY, MO. 25 000 GALLONS.
On tower 20 ft. high above roof of warehouse. Tank has 6 in. side and bottom and $3\frac{1}{2}$ in. roof, all reinforced with expanded metal.
"A Concrete Warehouse with Concrete Doors and Water Tank."
Engineering News, Vol. 58, p. 82 (July 25, 1907).

STANDPIPE. WALTHAM, MASS. 2 000 000 GALLONS.
Diam. 100 ft., 37 ft. deep.

TANK. GERMANY. 30 200 GALLONS.
"Der Wasserturm in Hard-Fussach," by Mich. Heimbach.
Beton und Eisen, Vol. 6, p. 247 (October, 1907).

TANK. SHANGHAI, CHINA. 90 000 GALLONS.
392 ft. high.
Beton und Eisen, Vol. 6, 270 (November, 1907).

1907. TANK. LINCOLN, ME. 108 000 GALLONS.
32 ft. diam., 16 ft. deep, 8 in. walls.

1908. 2 TANKS. CUBA. ABOUT 184 000 GALLONS.
34 ft. diam., 24 ft. 9 in. high, supported on a tower 39 ft. high. Dome bottom 30 ft. diam., 5 ft. deep.
Mix cement fill sand voids and mortar 20 per cent. and 25 per cent. excess stone voids + 15 lb. alum + 6 lb. castile soap.
"Discussion of the Design of Elevated Tanks and Standpipes," by Col. Wm. M. Black, U. S. A.
Transactions American Society of Civil Engineers, Vol. 64, p. 539 (paper 1116; September, 1909).

TANK. ATLANTA, GA. 100 000 GALLONS.
Hollow, chimney-like shaft, 30 ft. inside diam. at the ground, and 22 ft. inside diameter at 90 ft. above, supporting a cylindrical tank.
"A Novel Reinforced Concrete Tower and Tank," by R. B. Tufts.
Engineering News, Vol. 61, p. 22 (January 7, 1909).
"Reinforced Concrete Water Tower for the Atlantic Compress Company, Atlanta," by R. B. Tufts.
Engineering Record, Vol. 59, p. 9 (January 2, 1909).

TANK. CALIFORNIA. CAPACITY NOT GIVEN.
185 ft. high, 13 ft. outside diam., inside diam. 9 ft. to the 124 ft. level, at which point it is enlarged to 10 ft. 6 in.
"A Unique Water Tower," by Edward P. Bailey.
Municipal Engineering, Vol. 36, p. 281 (May, 1909).

STANDPIPE. NEW HAVEN, CONN. 375 000 GALLONS.
50 ft. in diam., 25 ft. high; walls 18 in. thick, reinforced with round steel bars.
"Mill Rock Water Tower, New Haven, Conn," by Edward E. Minor.
Proceedings of the Connecticut Society of Civil Engineers, 1908, p. 155.
Abstract *Engineering News*, Vol. 59, p. 191 (February 20, 1908).

2 STANDPIPES. CUBA. EACH TANK 129 000 GALLONS.
24 ft. 2 in. high, 33 ft. 8 in. outside diam., carried on double row of arch connected columns.
Engineering News, Vol. 59, pp. 471, 571 (April 30, 1908).

TANK. GERMANY. 42 500 GALLONS.
37 ft. high.
Beton und Eisen, Vol. 8, p. 242 (July, 1909).

1909. STANDPIPE. EMPALME, SONORA, MEXICO. 475 000 GALLONS.
30 ft. diam., 90 ft. high; wall thickness varies from 10 to 5 in.
Engineering News, Vol. 62, p. 635 (December 9, 1909).
Municipal Journal and Engineering, Vol. 28, p. 828 (June 8, 1910).

STANDPIPE. BRUSSELS, BELGIUM. 280 000 GALLONS.
Tower and tank 145 ft. high.
Cement Age, Vol. 9, p. 299 (November, 1909), by H. Prime Kieffer.

2 TANKS. SAN FRANCISCO, CAL. 32 400 GALLONS.
They are 17 ft. outside diam., 20 ft. deep, $2\frac{1}{2}$ in. walls, 14 ft. above ground, carried on 4-in. reinforced concrete slabs.
Engineering Record, Vol. 61, p. 726 (June 4, 1910).

TANK. CAJAME, SONORA, MEXICO. 60 000 GALLONS.
Dome supported bottom.
Engineering Record, Vol. 61, p. 248 (February 26, 1910).

TANK. MONTVIEW STATION, VA. 100 000 GALLONS.
30 ft. diam.
Engineering Record, Vol. 60, p. 447 (October 16, 1909.)

2 TANKS. PIOMBINO, ITALY. 330 000 GALLONS.
32 ft. 2 in. diam., 30 ft. 1 in. high.
"Water Towers at Piombino," by Carlo Carvopassu.
Preliminary and Interim Report of the Committee on Reinforced Concrete, Institution of Civil Engineers, p. 242 (June, 1910).

STANDPIPE. BRIDGEWATER, MASS. 413 000 GALLONS.
Built on the State Farm; 30 ft. diam., 78 ft. high; walls 20 in. thick at base, 12 in. at top. Mix $1:1\frac{1}{2}:3\frac{1}{2}$ of gravel. Inexperienced prison labor. Absolutely tight.

STANDPIPE. MANCHESTER, MASS. 1 060 000 GALLONS.
50 ft. diam., 72 ft. high.

STANDPIPE. LISBON FALLS, ME. 913 000 GALLONS.
50 ft. diam., 62 ft. high.

1910. STANDPIPE. WESTERLY, R. I. 650 000 GALLONS.
40 ft. inside diam., 70 ft. high, 14 in. walls.
Canadian Engineer, Vol. 19, p. 430 (September 29, 1910).
Engineering Contracting, Vol. 34, p. 284 (October 5, 1910).

STANDPIPE. IXELLES, BELGIUM. 212 000 GALLONS.
Le Genie Civil, Vol. 56, p. 445 (April 9, 1910).

STANDPIPE. MITTAGONG, NEW SO. WALES. 314 000 GALLONS.
40 ft. diam., 40 ft. high; walls $10\frac{1}{2}$ in. thick at bottom, $4\frac{1}{2}$ in. at top.
Engineering News, Vol. 63, p. 702 (June 16, 1910). (This tank failed.)

STANDPIPE. ROCKLAND, MASS. 1 300 000 GALLONS.
46 ft. diam., 104 ft. high.

STANDPIPE. CHERRY VALLEY, MASS. 200 000 GALLONS.
40 ft. diam., 21 ft. high.

STANDPIPE. ROCHDALE, MASS. 200 000 GALLONS.
40 ft. diam., 21 ft. high.

1911. STANDPIPE. ASHLAND, MASS. 300 000 GALLONS.
40 ft. diam., 32 ft. high.

"Handbuch für Eisen-betonbau," Vol. 5, p. 536, Ed. 2. Berlin, 1910. Wilhelm Ernst & Sohn. $4.40. (Thirty-three pages of descriptions, with illustrations, of concrete water towers of every kind, erected in all parts of the world, also standpipes.) (Jc–396a.)

"Water Storage in Elevated Tanks and Standpipes," by H. E. Horton. *Journal of the Western Society of Engineers,* Vol. 14, pp. 429, 432 (June, 1909). (Discusses the relative value of steel and concrete standpipes.)

"Concrete and Reinforced Concrete Construction," p. 689, by Homer A. Reid. New York, 1907. Myron C. Clark Pub. Co., 21 Park Row, New York City. $5.00. (Description of standpipes at Milford and Fort Revere, four pages.) (Jc–334.)

The following references were examined in compiling this list:

Engineering Index, 1884–Oct., 1910.
Engineering News Index, 1884–1909.
Minutes of Proceedings of the Institute of Civil Engineers, 1879–1910.
Engineering Digest, Jan.–Oct., 1910.
Proceedings American Waterworks Association, 1906–9, inclusive.
Proceedings National Association of Cement Users, 1905–9, inclusive.
Repertorium der Technische Journal-Literatur, 1903–8, inclusive
Catalogue of the Library.
Transactions American Society of Civil Engineers.

THE CHAIRMAN. — Mr. Arthur Maynard is the only one, apparently, who has ever built an absolutely water-tight standpipe, and I am going to ask him to tell us how he did it.

MR. MAYNARD. — I don't think I am engineer enough to tell you gentlemen about that work. Engineers know their business, and probably Mr. Wason knows wherein that standpipe differs from others and can tell you about it better than I can.

MR. WASON. — I wish Mr. Maynard would speak for himself. As he described it to me last week, he had a good quality of materials, which he carefully graded and mixed. He mixed them very thoroughly by hand and they were carefully deposited. The reinforcement to which I referred between floor and wall is, I think, quite different from what has been used before, and I believe that has quite a bit to do with it. It seems to stiffen that critical joint, and if you get by there without leaks you can go the rest of the way without great difficulty.

As I remember it, he ran his floors straight across to the outside with just a little offset downward and then a roughing strip. Then the wall was cast, dovetailed into the floor and a little fillet of concrete was placed between floor and wall and worked in with a great deal of care. Water was put in ten weeks after the foundations were started. The top of the concrete, the last to be placed, was about one month old. The standpipe is 30 ft. in diameter and 78 ft. high. It was made with prison labor, not skilled in any way in the mixing or placing of concrete. And yet, after one and one-half years' service, it is without a leak and has been absolutely dry from beginning to end, which I think is a matter of great credit to Mr. Maynard.

Mr. Maynard (*replying to a question*). — We used $1\frac{1}{2}$ in. angle rods. The first rods were 6 ft. high and the outside rods 10, and they went up at an angle of 4 and 6 ft. from the base.

Mr. FitzGerald. — What was the proportion of concrete?

Mr. Maynard. — One-$1\frac{1}{2}$-3, and 5 per cent. lime.

The Chairman. — Does Mr. Andrews agree with that idea as to the reason for the freedom from leaks?

Mr. Andrews. — Yes. I was employed as consulting engineer and advised Mr. Maynard to use that amount of reinforcement. I considered that more steel was needed at the base than I used at Manchester, and we adopted this same principle in the design of the standpipe at Rockland. I put in about three times as much steel here as was used at Manchester and carried one set of rods 5 ft. high, another 10 ft. and one 15, and one set of vertical rods was carried clear to the top. I think it prevents, to a certain extent, the tendency to spread at the base, where the critical point seems to be in nearly all reservoirs.

Mr. FitzGerald. — What are the sizes of the aggregate in this concrete?

Mr. Maynard — Crushed stone, stone picked up around the farm — field stone — screened through a $1\frac{1}{4}$-in. screen and all the fine stuff left out.

The Chairman. — It was a gravel?

Mr. Maynard. — No, field stone, picked up. There was no gravel at all. Our stone is quite coarse — hardly any of it will go through a 50-mesh or a 100-mesh screen.

Mr. FitzGerald.— The sand was clean and coarse?

Mr. Maynard. — Yes, sir; all bank sand.

Mr. Leonard C. Wason (*by letter*). — The writer has read with interest the paper of Mr. Andrews, and sees no ob-

jection, from a purely theoretical standpoint, to making the wall of a standpipe so strong that the concrete in tension will resist the water pressure. In the application he thinks there are exceptions that could legitimately be taken to some of the assumptions, and that there are a number of practical objections applying to this method of design.

The author mentions reinforcing against the bending moment between the floor and wall. Inasmuch as there is a joint at this point between days' works, in this structure preventing any strength in the concrete mass, and inasmuch as it is difficult for the steel to get such a bond in the floor and wall as to resist a bending moment due to the great water pressure, it seems to the writer improper to apply this term to the stresses which here existed. The writer believes that the sole stress to be here cared for is that of shear, and believes with Mr. Andrews that it is wise to use a considerable amount of steel for this purpose. The writer has observed leakage through horizontal joints where there was no evidence of vertical cracks in the vicinity and believes that there is no relation between leakage of one set of cracks and the other.

Mr. Andrews, after determining by test the ultimate tensile strength of a specimen of concrete about 4 in. square, makes the assumption that a larger mass is 25 per cent. stronger. The writer thinks it is unfortunate that the actual tests upon which this assumption is based were not given, inasmuch as tension tests are rare and therefore are of very great value to engineers. Any such tests have entirely escaped the search of the writer. If, however, this assumption is based on compression tests, a different conclusion will be reached by examination of recent tests made at the Watertown Arsenal. It would appear that large specimens do not develop so high a unit stress as small specimens of the same proportion of materials.

It is unfortunate, also, that the tests upon which the assumption that reinforced concrete develops 10 per cent. greater strength than plain concrete are not given. If this is so it would be extremely valuable to the engineering profession to have the actual data. The investigation of Professor Talbot, as given in the recent edition of "Concrete; Plain and Reinforced," by Taylor and Thompson, gives the conclusion that reinforcing does not affect the tensile strength. Mr. Andrews states, "If the section is reinforced, the ultimate fracture will not necessarily be at the point where the first crack develops. . . ." In the writer's opinion, ultimate failure *is* where the first crack develops

in his structure. An apparent increase of strength will be due to the steel solely. The writer's opinion, therefore, is that no greater stress can be theoretically assumed for tension in concrete than that obtained by actual tests of plain specimens and also that a suitable factor of safety should be allowed on this.

The solution of equation $422.65X + 9.35\ (10X) = 149\,500$ lb. is $X = 290$ lb. Where this is mentioned later it is referred to as 274 lb., which is an error; and where reference is made to the Lisbon Falls Reservoir, if the writer understands the condition correctly, the stress in the concrete should be 310 lb. instead of 235.

The writer also questions the ratio of 10 : 1 between the moduli of elasticity of steel and concrete. While this is doubtless as near correct as any ratio for a reasonable working stress of concrete in compression, Mr. Andrews is using a stress in his concrete almost up to the breaking point, and at this stress the modulus is considerably lower than at a reasonable working load; therefore the ratio is doubtless nearer 15 : 1 than 10 : 1. While it is doubtless true that the moduli of elasticity of concrete in tension and compression are somewhat similar, it has not been proved that they are absolutely identical. It seems too bad that Mr. Andrews did not state accurately the amount of water used in his mixture, and whether it was strictly uniform throughout the whole execution of the work; because the strength and density of the concrete vary with the amount of water used. With too much or too little, the strength is less and the porosity greater than with the very best proportion.

In the writer's experience it has been found necessary to place steel within 2 in. of the surface which is being protected from cracking by the reinforcement; less than 1 in. is very much more effective. If the steel is more than 2 in. away from the surface to be protected, it is wasted. In the design of a standpipe with heavy walls and one or at most two rings of steel to resist the water pressure, it is impossible to reinforce the inside face, which is the surface to be protected against cracks, because if the steel is placed close to the inside face, if for any reason the concrete did crack, the steel would not prevent failure of a structure, because the water would press the thin veneer of concrete outward between the rings.

Assuming the theory to be worked out correctly, the following practical objections seem to the writer sufficient to throw serious doubt on the value of this method of designing standpipes. In each of those in which the writer was interested at one

time during the placing of concrete, an accident occurred delaying the work sufficiently to prevent its being truly monolithic. It is easy to make the inside face absolutely dense as so to be water-tight. However, it has been found quite difficult where two rings of steel have been used, and somewhat less difficult with a single ring to get absolute density around the bars. Any voids at this point reduce the cross-sectional area which is counted upon to resist tensile stress from water. There would also be an unequal stress on the inside and outside of a thick wall due to their distances from the center. The nature of these stresses makes it difficult to determine accurately their value, but it is probable that they would affect the uniformity of strength over the whole section somewhat. Moreover, shrinkage in a rich mixture of concrete setting in the air frequently produces cracks; and the larger the structure the more probable it is that cracks will actually exist. A single crack is sufficient to destroy the theory of the design. If the tank escapes cracks due to these causes when in service, it may receive them due to the difference in temperature in different seasons of the year between the outside and the inside. Finally, in actual tests made on beams where two identical specimens were made from the same batch of concrete, there was quite a wide difference in their strengths, and marked differences were noted between the strength of different batches. This irregularity, even when conditions are arranged for uniform and perfect results, is sufficient to throw doubt upon uniformity of the tensile strength of concrete throughout so large a structure.

By reference to the list of completed standpipes accompanying this discussion, it will be noted that several successful ones had thin walls, notably the one built years ago at Hull, Mass.

Mr. A. B. MacMillan. — It was determined at the very start of the building of the Westerly water tower that we should depend on a very dense mix of concrete to insure water-tightness, and in order to attain this result a large number of tests were made to discover the proper mixture for obtaining the maximum density with the aggregate at the disposal of the builders, and then to insure every batch of cement being as nearly as possible of the predetermined density. The first step was to make mechanical tests of the sand and stone available.

Two sizes of sand were tried, one a bank sand of the size commonly known as paving gravel and called No. $4\frac{1}{2}$, and the other a fine bank sand known as No. 5. Crushed gray Westerly granite of all sizes between $\frac{1}{2}$ in. and $1\frac{1}{2}$ in., as screened at the

crusher, was the stone used on this work. For testing purposes, 100 ounces of material were used at a time. Samples were selected from the pile by quartering, in order to get as nearly as possible average results. As the screens were not calibrated, values from Taylor & Thompson, page 194, were used. The first sample of stone, known as No. $4\frac{1}{2}$, gave the following results, the weights given being in all cases the amounts retained on the screen.

SAND NO. $4\frac{1}{2}$.

Size Inches.	Percentage Retained.	Size.	Percentage Retained.
1	$1\frac{1}{2}$	No. 8	39
$\frac{3}{4}$	$5\frac{1}{2}$	20	62
$\frac{1}{2}$	$15\frac{1}{2}$	30	$81\frac{1}{2}$
$\frac{3}{8}$	20	50	95
$\frac{1}{4}$	$26\frac{1}{2}$	100	98
$\frac{3}{16}$	31	200	100
$\frac{1}{8}$	38		

The fine sand, known as No. 5, when screened gave the following results.

SAND NO. 5.

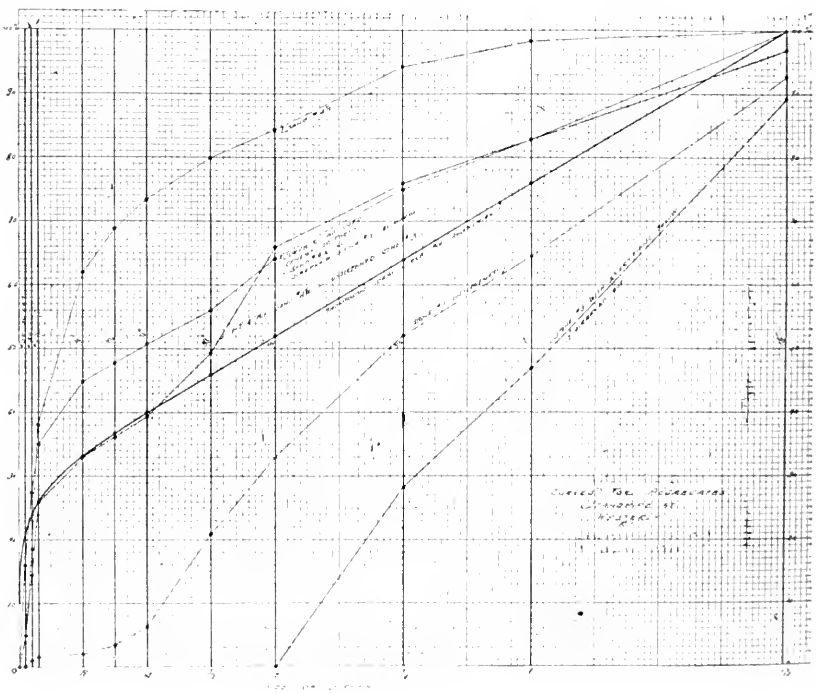
Size Inches.	Percentage Retained.	Size.	Percentage Retained.
$\frac{1}{2}$	$2\frac{1}{2}$	No. 20	37
$\frac{3}{8}$	$5\frac{1}{2}$	30	65
$\frac{1}{4}$	$9\frac{1}{2}$	50	$91\frac{1}{2}$
$\frac{3}{16}$	$12\frac{1}{2}$	100	97
$\frac{1}{8}$	17	200	$99\frac{1}{2}$
No. 8	$18\frac{1}{2}$		

The fine sand (No. 5) did not seem, however, to be as good quality as the coarse sand, there being a considerable amount of dirt in it, so that it was decided not to use this. Three samples of stone were then tested, and of these the results obtained with No. 3, the one used, are given below.

STONE NO. 3.

Size Inches.	Percentage Retained.	Size Inches.	Percentage Retained.
$1\frac{1}{2}$	$7\frac{1}{4}$	1	$96\frac{1}{2}$
1	$35\frac{1}{2}$	$\frac{1}{8}$	98
$\frac{3}{4}$	48	No. 20	$98\frac{1}{2}$
$\frac{1}{2}$	67	30	99
$\frac{3}{8}$	79	50	100
$\frac{1}{4}$	$93\frac{1}{2}$		

This stone (No. 3) was used with the coarse sand (No. $4\frac{1}{2}$) and Vulcanite Portland Cement in the proportion of one part cement, two parts sand and four parts stone, and tested. The curve obtained by this combination is shown by the *dotted line* on the chart. It was obvious that No. 3 stone and No. $4\frac{1}{2}$ sand, as they stood, could not be combined into a good curve. It did seem possible, however, to modify this by screening, and after careful consideration it was decided to remove from the stone everything that would pass a half-inch screen. This screening was done by hand on a small screen. A second trial was then made using a mixture of 16.9 parts Portland Cement and 28.7 parts sand and 53.5 parts of stone by weight. This mixture gave a curve that was practically coincident with the "Ideal" curve recommended by Taylor & Thompson. Trials for density were then conducted.



For this purpose a cylindrical can made of riveted $\frac{7}{16}$-in. steel plate was used. This can was 10 in. in diameter and 15 in. in depth. Fifty pounds of material was mixed in a metal box by hand, and enough water was then added to make a mix that

would barely quake when mixed. The concrete thus formed was then transferred to the cylindrical can and the distance down from the top of the can to the top of the mixture was carefully measured. The densest mix obtained was found to measure 7 in. down from the top of the can, thus giving a total volume for the 50 lb. of concrete of 610 cu. in. It was also determined that a variation of $\frac{1}{8}$ in. in height of mixture in the can above the mark set by this densest concrete corresponded to a change in volume of 1.6 per cent., thus giving a handy means of comparing any trial mixture. The density tests showed that the mixture giving a curve most nearly approximate to the Taylor & Thompson "Ideal" gave an excess volume over the best mixture of 6.4 per cent. and it seemed also to be lacking in mortar.

It was then decided that the concrete should be mixed so rich as to make only 12 cu. ft. to a 4-bag batch. The later result was finally obtained with a mixture of 20 parts by weight of cement, 40 parts of No. $4\frac{1}{2}$ sand and 40 parts of No. 3 stone screened to remove everything below one-half inch. This mixture had the maximum density of any that was measured and appeared to be satisfactory in other respects. The curve given by this mixture, however, on volumetric tests, was nearly 10 per cent. higher than the "Ideal" of Taylor & Thompson at the point of tangency. In an endeavor to get even greater accuracy, a can of smaller diameter than the first was made, and further tests conducted with this. Twenty-eight various mixtures were tried, using this small diameter can, but the mixture mentioned above still showed the best results of any tested and it was accordingly decided to use this on the work.

Further tests were conducted for the purpose of ascertaining whether or not even greater density might be obtained by the addition of hydrated lime to the mixture. It was found that with the densest mix the addition of hydrated lime increased the volume almost directly in proportion to the amount of lime used and therefore it was considered of little use to add lime to the concrete.

In the course of the actual work on the standpipe, volumetric tests were not made every time samples were analyzed, but only when they varied two or more per cent. from those in use was the curve of the mixture worked out. As the sand and stone used were measured in wheelbarrows, the quantity was subject to an unavoidable variation of two or three per cent., so that it was believed to be an unnecessary refinement to carry the curves to any greater accuracy.

The amount of water added was given a great deal of consideration. It was found, I believe, that a paper recently read by Mr. Chapman before the National Association of Cement Users, gave some data on this point, that the percentage of water added to concrete in mixing has a very marked effect upon its permeability and that even very slight variations from the proper constituency give very much greater variations in permeability; that is, if too much water is added the resulting concrete is much less waterproof than one with the ideal amount of water. This ideal amount varies, however, for different mixtures of cement and aggregate, and the nearest approximation that can be made offhand is that enough water shall be added to make a mixture which under tamping shall show water at the surface and give what we call a dry quaking mix, that is, a mix that will not quake until it has been thoroughly tamped. With any given cement and aggregate, preliminary tests may readily be made to determine the proper amount of water to use in mixing. Once the amount which gives a dry quaking mix has been found, it is simply a matter of adding this proportion of water to each batch of concrete.

In the actual mixing of the concrete on this job we followed a method different from our usual one. One half of the stone was put in the mixer and some water. The mixer was then revolved for a minute or so and the sand and cement and the rest of the stone and water were added. The concrete was then thoroughly mixed for a total time of about five minutes, when the mixture was dumped and hoisted up on to the tower.

The tests described were conducted by Mr. W. W. Clifford, of the Aberthaw Construction Company.

Mr. Desmond FitzGerald. — That wasn't what you'd call " sloppy " concrete?

Mr. Macmillan. — It was not. It was a little bit drier than that. Water flushed freely to the surface when it was tamped, but it was not what you' would call a quaking gelatinous concrete.

Mr. FitzGerald. — How much did you put on at a time?

Mr. Macmillan. — About 6 in. at a time. We went around the standpipe both ways, so that there was no part in a single layer that was left standing to form a weak spot.

Mr. FitzGerald. — That gave you 3 ft. a day?

Mr. Macmillan. — That was about the average.

Mr. Bertram Brewer. — The Waltham reservoir is very thoroughly described in the volume of the *Journal of the New*

England Water Works Association for 1907; but perhaps a brief review of the facts in connection with it may be of some interest.

It was built in 1906, and it has seen four years of service, which makes it rather interesting and rather older than some of the others built under these new designs and these new ideas gained from the experience now available.

When this reservoir was built there was a feeling abroad that the construction of concrete reservoirs was rather a difficult operation. Much doubt was also felt as to the possibility of making them watertight. Great difficulty had been experienced in other places and we made a very careful study of the problems in Waltham.

The difficulties connected with construction, which at the inception of this work seemed paramout, and prevented several contractors from bidding on it at all, were carefully considered by the city's engineers. After it was found that a reliable firm would give us a reasonable figure and before the contract was let, conferences were held with the firm and its engineer and suggestions were exchanged as to details of forms and method of supporting the same. The lattice-work supports which so successfully held the reinforcing rods in their proper place were suggested to him. In fact, the methods of construction were thoroughly worked out in the minds of the engineers who planned this work, before we asked for bids. It only remained to agree with an intelligent and resourceful contractor upon details.

We went into the question of impermeable mixtures, the best kind of materials, of aggregate, and the use of hydrated lime or other water-proofing ingredients. After very careful study, the speaker concluded that a concrete reservoir could be built in Waltham at a reasonable cost, but was not by any means assured that it would be watertight. As a matter of fact, we concluded, after much thought, that if it was not absolutely watertight it would not necessarily endanger the structure as a whole; that it would remain sound and at the same time might show considerable seepage.

Now the speaker has found that, in most places where these reservoirs have been built, the general idea is, at the start, that the builders expect to get absolutely watertight structures, whereas in practically no case has this been accomplished. We do not think it makes much difference if it has not. Our city government was so informed. They were frankly told that a concrete reservoir ought not to cost as much as a steel standpipe, that it would be better for the water supply, — we should get better

results in the water that we drank, and the maintenance would be very much less, — that a concrete reservoir would probably last years and years longer than a steel reservoir, and, altogether, if they wanted to put the money into it, it was a good proposition. That is the way it was put up to them. They were warned, moreover, that a few months or a year after it was built the daily papers might have articles to the effect that the reservoir was leaking and dangerous, but that they must not mind that, because we expected it would leak, but that it wouldn't do any harm.

With these facts before them, they decided to build. The contract was let and the reservoir cost about three thousand dollars less than a steel one of the same dimensions would have cost. The actual cost of the Waltham reservoir is in the neighborhood of $26 000.

Fig. 1 is a picture of the finished structure. It is about 43 ft. high and 100 ft. in diameter, and contains 2 000 000 gal. of water. No effort was made to give it a smooth finish on the outside, — that is, as to the details of finish of the concrete itself. But we did make it of such proportions and provide such embellishments as to make it very attractive from a distance. There seemed to be no need of spending money on a surface finish up there in the woods. It certainly is a great addition to the landscape and can be seen from a great distance.

Fig. 2 shows the joint at the base about which so much has been said. At the Waltham reservoir we never have had any difficulty or leakage at that point. Of course, the stresses are not so great in this as in the higher reservoirs, the high-water mark being slightly less than 37 ft. The forms also show in this view. They were of wood in sections, bolted together through the wall.

Fig. 3 shows the supports of lattice-work, which were built up as the wall progressed. This view shows the operation of cleaning out the old concrete and getting ready for the new work, the details of which have been previously described.

Another view, Fig. 4, shows the same section in another part of the wall and shows the round rods which are arranged in the lower part of the wall in three rows. It also shows how the two sets of forms were supported by each other. The bolts which went through the wall are also apparent. These bolts were in three sections, the middle section being left permanently in the wall.

The roof of this reservoir is quite novel. Use was made of the overflow pipe as a central column. This pipe was embedded

in the concrete and steel trusses radiate from it to the wall. The roof surface consists of a concrete slab.

Another view, Fig. 6, shows the outside of the reservoir when about half completed. It shows the method of building the staging and the manner of caring for the concrete during dry weather.

Fig. 7 is a view of the completed reservoir some weeks after it had been put into use. At the first there was considerable seepage and the lime began to appear on the surface so that the stalactite formation became very noticeable. After a few months' use the moisture was very much reduced, so that there was practically very little seepage, and it seemed as if after a while it would stop altogether. This has not proved to be the fact. There is now considerable seepage when the reservoir is filled, but it would be practically impossible to collect any amount of water from the outside walls if it were kept full all day. There can be no doubt that infinitesimal cracks do appear in the concrete when fully stressed; and, the joints being the least impermeable place, most of the moisture shows up there. The reservoir is rapidly acquiring the appearance of an ancient and attractive old castle. A little ivy judiciously planted would make it in time exceedingly attractive. Its dark appearance is mostly due to organic growths on its sides and their decay.

It took about two days to go around this reservoir, to make one section $3\frac{1}{2}$ ft. higher, and it was very much easier to make inclined joints between two days' work, letting the concrete flow naturally. After full consideration, it was decided to allow that sort of thing, and the diagonal lines near the top show such joints. Of course it left the joint in a bad position to clean out, but we found it was just as successful as the other way and there is no more leakage at that joint than at any other. In fact, our experience went to show that a wait from one day to another, or even a delay of two days, was not very serious. But, if it went two or three days or more, it was very difficult to get a good, tight joint. In one case, when about one third built, the work was delayed for five days. The particular joint where this delay occurred shows the most seepage of any in the whole reservoir. I think that is all I have to say in regard to the views, but I have one or two things to say in closing.

Our experience certainly shows this, that a contractor should have the best of organization to build one of these reservoirs, because no delay should be allowed — it should not be considered for a moment. I also want to refer to what Mr. Allen has said

in regard to temperature stresses. I don't know what a stronger concrete would have done to eliminate seepage in the Waltham reservoir, but I do know, as has been said of the Manchester reservoir, that most of the seepage has been where the sun strikes the wall. On the north side there is almost no seepage, and never has been from the beginning. This practical fact is very important, and shows that the temperature stresses have an important influence on seepage, which designers who prophesy an absolutely water-tight job would do well to remember. And then I want to leave this impression in your minds if possible; from the start to the finish we have never had any repairs to make or any questions at all as to the stability and soundness of the structure.

Just one word in regard to the character of the concrete that went into the Waltham reservoir. I had the best inspector to be found in the city of Boston — one of the best, I think, anywhere. As a matter of fact, we had two inspectors, one man at the mixer and the other on the wall at the critical part of the work, and the speaker doesn't believe better concrete could be made than that which went into the Waltham reservoir. Somewhat better work could be done at the joints, but it would be very difficult to make a great improvement there. In cases where the joints stood for any length of time, say more than two days, the speaker would insist on having a newly picked surface, a brand new face on the old cement to begin new work upon. Other than that — and much thought has been given to the subject as well as considerable investigation and some further experience — it seems impossible to improve on the workmanship of that job. One leak developed, and that at a point where the inlet pipe went through the wall. It was a very small affair, due to a slight settlement, but water did flow out through it. And that leak was stopped up with lead wool by an ordinary workman.

Mr. Howe. — Does the freezing of the concrete where it is saturated with water cause any disintegration?

Mr. Brewer. — We have had hard winter weather in Waltham in the four years of its use, seasons when the thermometer registered several degrees below zero several days in succession, and there has not been so far the slightest disintegration noticeable in any part of the structure. The large body of water is frequently renewed and is always in motion. As it is a ground water, it is comparatively warm in winter and seldom, if ever, freezes.

Mr. Andrews. — The Waltham reservoir is an illustration of a 1-2-4 concrete. I do not think a 1-2-4 concrete can be made entirely impervious to water. The concrete in Waltham was made with the greatest care, under the strictest inspection and with the utmost care in grading of all materials. Five per cent. hydrated lime was also used. Now, in the Lisbon Falls reservoir the richness of the mix was increased to 1-1½-3, but with the increased head we had there of 62 ft. in comparison with 37 ft. at Waltham, we had absolutely no leakage and not enough seepage to cause any very great amount of efflorescence on the walls. I believe in using cement enough to make the concrete watertight.

Mr. Carpenter. — Was the joining of one day's work with another in both those reservoirs made in the same manner?

Mr. Andrews. — Practically in the same manner. In the Waltham reservoir we washed out with the hose, scraped the surface and applied cement grout. In the Lisbon Falls reservoir, we employed the same method, except that we inserted on the inside of each of the walls a triangular strip 1½ by 2 in. to break the joint through the walls.

Mr. Sanford E. Thompson. — There is a question in my mind whether the difference in the leakage of those two reservoirs is not to quite an extent due to gaining experience in the later reservoirs. Mr. Andrews says the work was practically the same, and yet I think he will agree that the work of cleaning off those surfaces to make the joint was probably very much better in the later work. In the Waltham reservoir, as I remember, there were some small tubes run through the wall and the forms were bolted together. And I remember that those tubes, at that particular time, came right out of the surface of the concrete, and there was a little depression owing to those tubes. Those tubes were pieces of pipe surrounding the rods that went through, and in the joint that I saw there was a small depression under those pipes which would naturally let water through there. Now that construction was changed in the later reservoirs, was it not?

Mr. Andrews. — The tubes Mr. Thompson refers to were not really tubes. The method we had for holding our forms together was a steel rod threaded at each end, on which were screwed two threaded sleeves coming to within 1½ in. of the outside of the forms. Bolts went through the forms and through these sleeves. When we took the form down we unscrewed the outside bolts and plugged up a hole about 1½ in. deep with cement

mortar. These rods did run through very close to the upper surface of the concrete, but no very great proportion of the seepage was at those spots where the rods went through. Nevertheless, we did change the location of those rods on future work so that they were completely embedded in the wall.

Mr. Carpenter. — Mr. Andrews states that after the concrete was cleaned off there was an application of grout, or rich mortar. Was that done in the Waltham case, or was the concrete placed on the absolutely clean surface of the previous day's work?

Mr. Andrews. — The grout was applied. Very great care was taken on succeeding work as knowledge was gained which showed that it was required.

Mr. F. A. Barbour. — I have a few slides illustrating the standpipe at Attleboro, which I will present. The first view shows the foundation of clay marl. Under the walls the masonry foundation was carried to a depth of 5 ft.; under the floor to a depth of 2.5 ft. The reinforcement in the lower section of the tank well is shown in the next view, which calls attention to the large amount of steel required. The limited space between the bars rendered the placing of concrete difficult, and probably accounts to some extent for the leakage which has developed in this section of the structure. The steel used was 0.40 carbon, too hard to be bent to the required circle, and necessitating the use of rolls, which did not develop the true curve to the extreme end of the bars — a result shown in the same view where the tendency of the steel to kick out at the joints is evident. The next view shows the form used in construction of the walls.

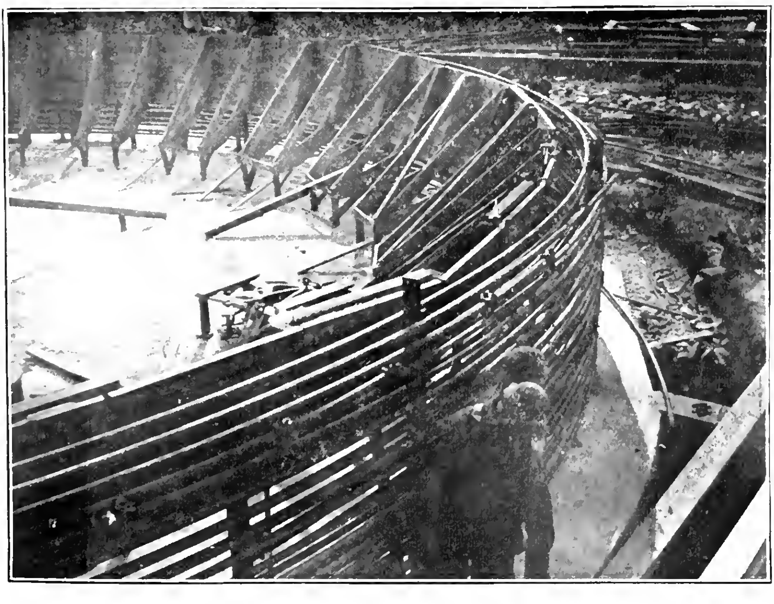
The Chairman. — Were those forms bolted through the walls?

Mr. Barbour. — No, just bolted together at the connecting ends.

On the completion of the foundatio a timber tower was erected in the interior of the tank to a height of 60 ft., and on this tower a derrick was raised and maintained at this elevation until the tank had been constructed to the top of the tower. The tower was then carried up to an elevation of about 110 ft. and the derrick again raised. This tower was independent of the walls and served merely to support the derrick and dumping platforms from which the concrete was shoveled into the forms.

The tank was kept filled with water during construction to a level of about 20 ft. below the point where concrete was being placed — principally as a protection to the workmen. Whether

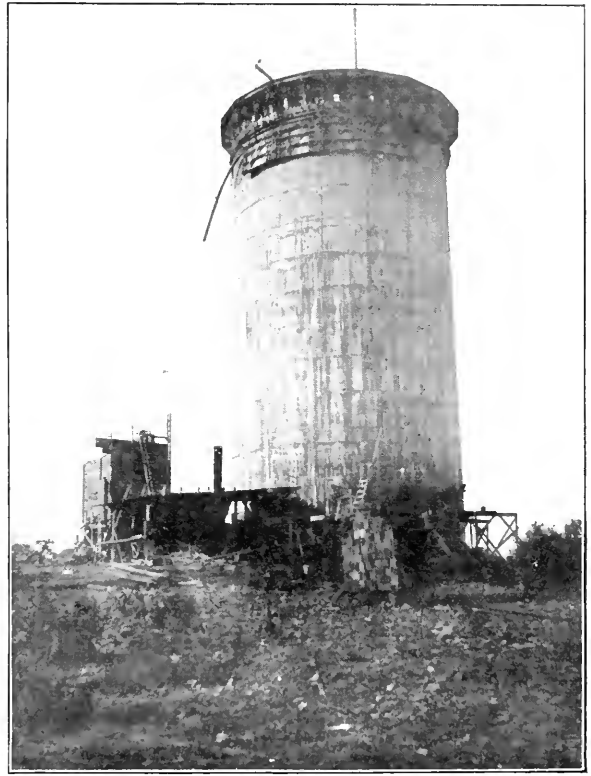
Foundation of Clay Marl.



Reinforcement in the Lower Section of the Tank Well.

Form used in Construction of the Walls.

Method of supporting Horizontal Reinforcing Bars.

Standpipe at Attleboro, Mass.

it is advisable to allow a thin reinforced wall to set with one side covered by water and the other exposed to the air may perhaps be questioned.

The outside forms which were made in sixteen sections about 7 ft. high with horizontal ribs and vertical lagging and locked together at the ends by clamps on the ribs, were provided in two sets, one above the other. The interior forms were constructed by vertical ribs on which horizontal lagging was laid as the work of placing the concrete progressed.

The method of supporting the horizontal reinforcing bars is shown in the next view. Vertical 4-in. channels, spaced about 11 ft. apart, in the wall circle, were erected with rods passing through holes punched in the flanges and spaced so as to hold the horizontal bars at the desired distance apart.

The gate valves are equipped with hydraulic cylinders, electrically operated, thus permitting the standpipe to be cut out either from the office of the superintendent or the pumping station.

The inlet manhole is set in the bottom of the tank, and is reached through a masonry tunnel leading from the lower floor of the gate chamber. The manhole cover is attached to a counter-weighted cast-iron beam supported on a pedestal in such a way that, when the bolts of the cover are loosened from below, the counter-weight lifts it from its seat and permits it to be readily swung around out of the way.

The inlet pipe is carried to a height of about 40 ft. above the floor; the outlet is through a pipe extending 1 ft. above the floor, check valves insuring circulation. A recent examination of the inlet pipe shows it to be badly tuberculated — a condition resulting from the character of the water.

An attempt was made in the Attleboro standpipe to improve the appearance of the structure by an ornamental cornice. As seen from a short distance the result is successful, but from more distant points — and the tank is visible for miles in all directions — the cornice adds but little to the effect. When concrete was first proposed for use in standpipes, the possibility of making these structures an addition to the landscape, or at all events, an improvement over the old steel tanks at once suggested itself. Doubtless this can be done by adopting structural lines of such character or in such bold relief as to be effective at a distance, but to do so costs money, and authorities usually do not feel justified in using the available appropriation for esthetic effects. At a reasonable cost, however, concrete

tanks may be greatly improved in appearance over those constructed to date, all of which show horizontal form lines which might at small expense be removed.

The new basis of design adopted by Mr. Andrews in which dependence is placed on the tensile resistance of the concrete, and the working stress of the steel so reduced that the resulting deformation will not crack the concrete, is of particular interest to designers of reinforced concrete structures intended to hold water.

The general practice has been to stress the steel from 12 000 to 15 000 lb. per sq. in., and to take no account of the tensile resistance of the concrete, building a wall thick enough to contain the metal and permit the placing of the concrete. Since the deformation of steel stressed in excess of about 4 500 lb. per sq. in. exceeds the ultimate elongation of plain concrete, the construction of tanks in which the steel is worked at much higher stresses necessarily involves the cracking of concrete. The unknown factor in the problem has been as to the effect of the steel in developing a greater elongation in the reinforced concrete before final rupture than would be the case in plain concrete, or in distributing the deformation in the concrete into such a multiplicity of minute cracks that leakage would not result, or if it did result these minute cracks might be spanned by an elastic wash or coating. Mr. Andrews' conclusion that in the Attleboro tank vertical cracks must have developed is not only true but inevitable from the basis of the design. His assumption that such leakage as has occurred — which it may be stated is less than in any other standpipe which I have had opportunity to examine, except those at Bridgewater and Westerly, R. I. — results from these vertical cracks, is not a necessary corollary. From the most careful examination of the Attleboro tank there has been found no relation between the location of the leakage and these internal vertical cracks, as indicated by the water marks on the internal surface when the standpipe is drying out. It is true that in the critical section where the side walls, subject to stretch, join the bottom, there is a horizontal crack near which most of the leakage has developed, but even here, as appears from the work recently done in stopping these leaks, the explanation is found as much in imperfect concrete as in the existence of the horizontal crack.

Some months ago a successful attempt was made to stop the several leaks, then apparent, by grouting, and the method used may be of interest. On the assumption that the repairs should

be made when the wall was stretched to the maximum limit, the work was done with the tank full. At the location of each leak a hole, larger on the inside, was cut into the wall exposing the steel. This hole was filled with small crushed stone, held in place by a piece of wire netting, and the whole plastered over with mortar, a short length of $\frac{3}{4}$-in. pipe passing through this plaster. Neat grout was mixed and poured into an 18-in. length of 6-in. wrought-iron pipe with flanged top and bottom. From the bottom a lead pipe connected with the pipe in the wall, and to the top a large carbonic acid tank under 3 000-lb. pressure was connected. By a valve any pressure could be brought to bear on the grout, shooting it into the hole in the wall back of the hardened plaster facing. As much as $\frac{1}{2}$ cu. ft. of grout was forced into the wall at one point, and through it for a distance of several feet where it again made its appearance at the surface. Obviously, the conditions found suggested that the leakage was here due more largely to imperfect placing of the concrete around the steel, which was too close together, than to the horizontal crack resulting from the deformation of the wall.

It is of interest to note that the steel when exposed was bright and clean.

In the Attleboro tank there have been from time to time a few small leaks, but at no time has more than one per cent. of the entire surface been even damp, a result that indicates that 1-2-4 concrete, properly placed, can be made watertight, although it may be better judgment to use a richer mixture.

It is not intended by the foregoing statement to assert that the deformation of concrete beyond its ultimate elongation is not the cause of leakage, but merely that in the Attleboro structure this result has not been indicated by the actual location of the leakage. That leakage increases with changing deformation is, however, made evident by the fact that the tank, if kept full, or at a nearly constant level, tends to become absolutely watertight. If, however, the tank is emptied and refilled, the leakage is always greater than before emptying — presumably the lime carbonate which had plugged the openings being crushed by the contraction of the steel as the pressure is removed. Again, it is of interest to note that there has been no leakage at the point where the gatehouse joins the standpipe. Whether this is because the gatehouse is on the shady side of the wall, or because its serves as an anchorage from which deformation starts, is perhaps debatable.

Returning to the basis of design adopted by Mr. Andrews

there can be no question that if by working the concrete in tension the stresses in the steel can be kept below the point where the stretch of the wall will crack the concrete, one possible cause of leakage will be removed. It is to be noted, however, that if because of imperfect placing a weak point is developed and the concrete cracks, the steel will be deformed more than under the basis of design used in other tanks; and herein lies the risk. Further, it would seem that Mr. Andrews has failed to take into account the contraction of the concrete in setting, with the resulting condition that the concrete is already in tension and the steel in compression. How far this will reduce the effective strength of the concrete in resisting bursting stresses, and just how the two materials will work together in a relatively thick wall, must be demonstrated.

There is, however, little question that a thicker wall than has been used in the past is advisable, if only to discount the personal equation in the placing of concrete, and to provide more space for the steel. Further, experience has clearly proved that such reinforcement at the connection of the wall with the bottom of the tank, both with vertical members, and by the adoption of a working stress in the horizontal members gradually increasing from the level of the bottom upwards, so as to distribute the deformation over a greater vertical distance, is necessary in order to avoid the trouble which has occurred at the junction of the side walls and the bottom of the tank.

Mr. FitzGerald. — Would not the tank become watertight if it had been plastered on the inside?

Mr. Barbour. — The tank was plastered, and was given numerous coats of the Sylvester wash of soap and alum.

Mr. FitzGerald. — You spoke of being able to make concrete absolutely watertight without anything except the concrete itself.

Mr. Barbour. — Yes, sir; I believe that can be done.

Mr. FitzGerald. — It is very difficult, is it not, to make a mixture absolutely watertight?

Mr. Barbour. — Not if it is rich enough and placed as it can be placed. In other words, I think that most of the leakage is due to a failure to properly place the concrete. No class of structure depends more on the personal equation than a concrete standpipe.

Mr. FitzGerald. — Does not the plaster, put on the inside, add very much to the chances of making the tank watertight?

Mr. Barbour. — Not if you stretch the steel so that the

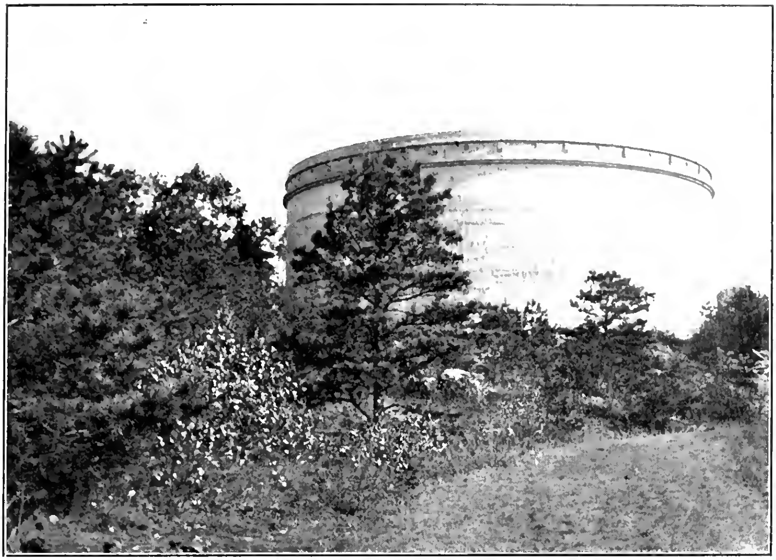


Fig. 1.

Fig. 2.

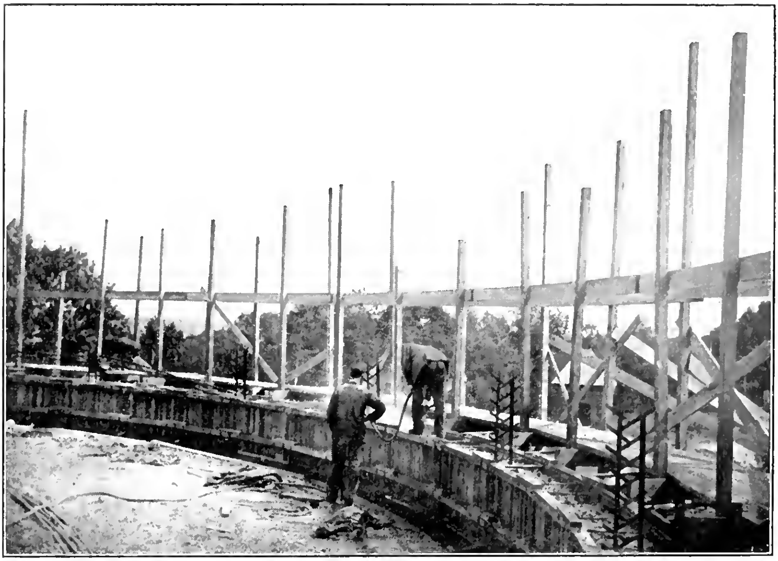


FIG. 3.

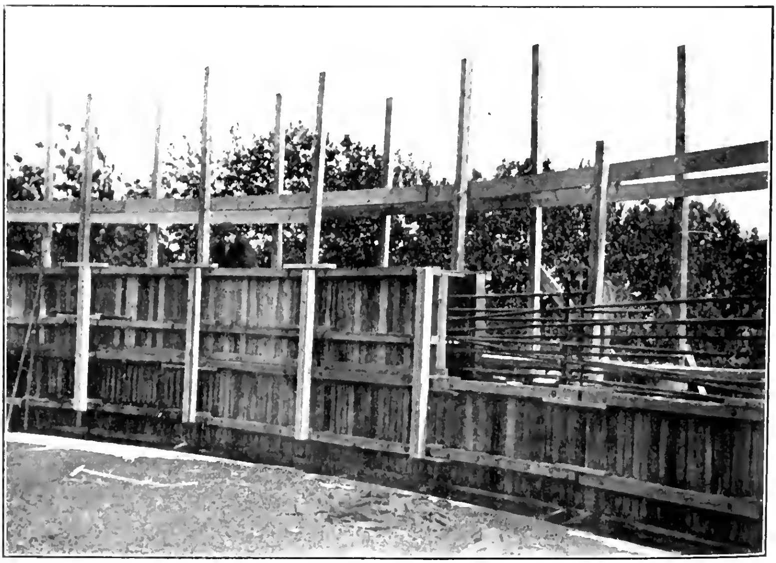


FIG. 4.

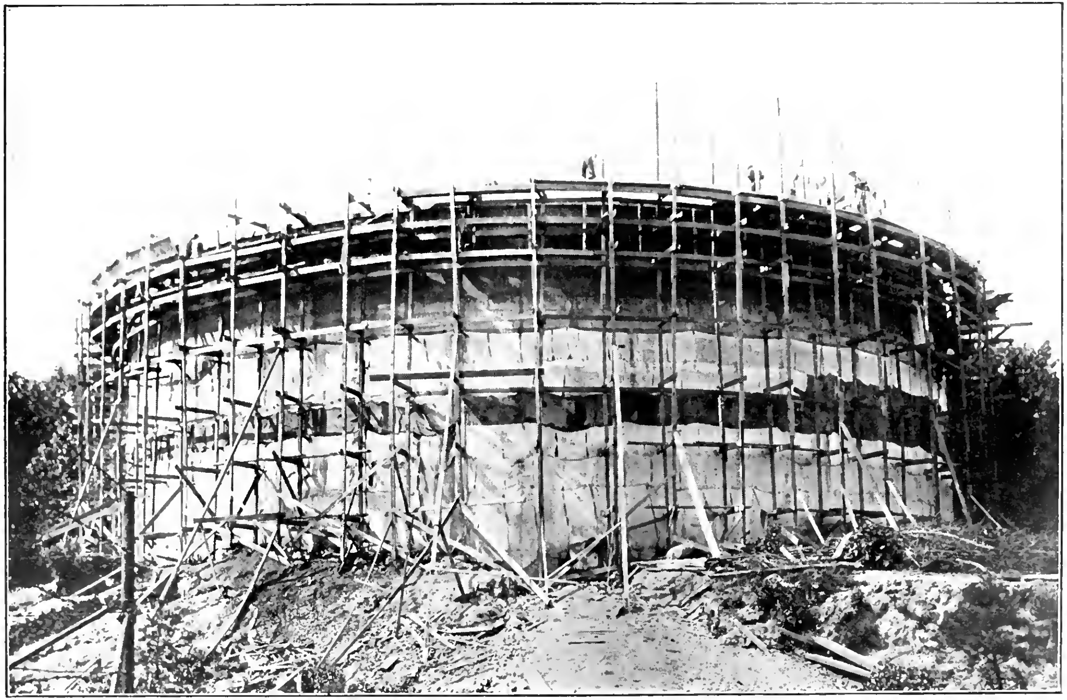


Fig. 6.

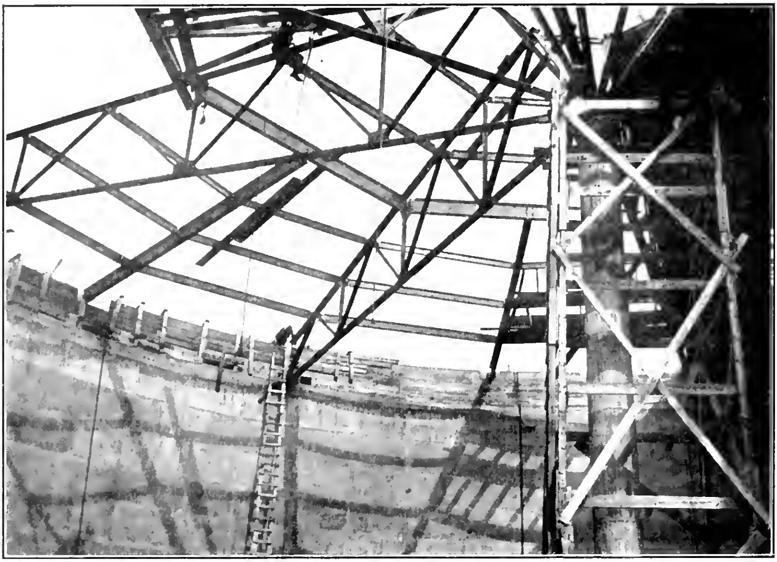


Fig. 5.

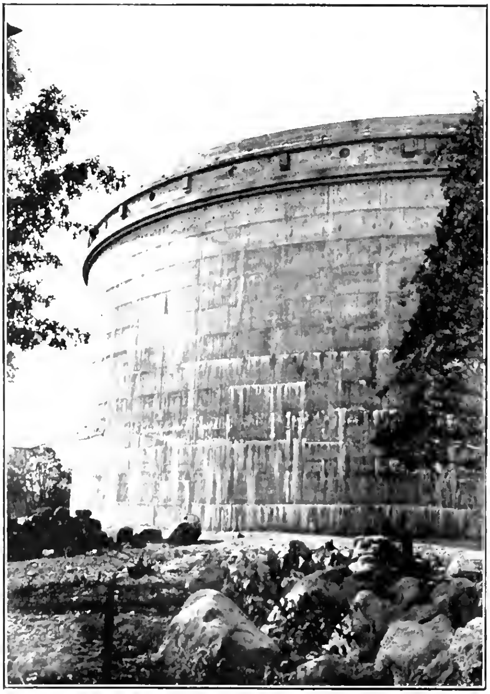


Fig. 7.

deformation of the walls cracks the concrete. The plaster is not elastic, and will also crack.

Mr. Barbour (*by letter*). — I am advised that the tank at Rockland has been put in service since the paper was presented, and I would ask Mr. Andrews if his anticipations in regard to leakage have been fulfilled.

Mr. Andrews. — I agree with Mr. Barbour that it is necessary to make concrete and place concrete as perfectly as possible. Answering his question as to the tensile stresses which develop in the concrete, I will say that the concrete in the Rockland reservoir was placed with that in view. The forms were 2 ft. 7 in. in height. Our capacity was such that we could fill those forms in about two hours. The concrete was laid in 4- to 6-in. layers, and it took practically half an hour to go around. One layer was immediately followed by another layer, so that there were no vertical joints at all between the layers, and I saw no reason why the concrete, when so well reinforced, should not be stronger than concrete in briquettes.

Mr. George H. Snell.* — I do not know but Mr. Wason and Mr. Barbour have covered the whole situation thoroughly. But I might say I think people are liable to get an exaggerated idea of the amount of leakage in the Attleboro standpipe. It has been very little from the time it was built up to the present. The efflorescence shows on the outside in those pictures which were taken in the fall of 1905, when it was completed, so that they really show it in the worst stages of the seepage on the outside. I think one of the pictures was taken before it was completed and before it was plastered. One of the interior pictures Mr. Barbour showed was where the first coat of plaster was put on, being a scratch coat. Another coat of plaster was put on over that, but it really didn't seem to make any great difference as to the amount of leakage. As we carried it up at the time of the building it was leaking then, I presume, at its worst; and a very careful estimate of the extent of the leak, as near as we could measure, was about one eighth of an inch in twenty-four hours. So that you can see at that time the amount of the leakage was not very great.

The leaks that were grouted this spring, two of which were on the east side, have shown from the time the work was started, when we began filling the standpipe as we built up. The other was on the southwest side of the tank and showed so that there was

* Superintendent Attleboro Water Works.

a spurt at certain times. We plastered that and so dammed it up that it showed two or three feet above it on the outside of the outer row of steel. On digging into it we found that the leak followed the channel down. It might appear that to get concrete tamped around the channel would be quite a stunt, considering that the space between the $1\frac{1}{2}$-in. round steel bars was only 4 in. on centers, leaving $1\frac{1}{2}$-in. space, thus giving very little chance to tamp it; and unless we were particularly careful, it would be surprising if there were not void places in the building. In grouting I think we practically stopped those leaks.

Speaking of the fine cracks on the inside, they show at places where it is absolutely tight opposite those places; so that in some cases, I presume, the leakage might follow down those channel irons for some distance. Also the leaks appeared on the east side. In the summer, in the morning about ten o'clock they were not pronounced; and then in the afternoon they started up around on the southeast side. On the north side of the standpipe, the northwest and the northeast, it is practically tight, with the exception of the seepage that seems to come through the concrete. I don't know, as Mr. Brewer says, that it is really any great disadvantage, except for the looks of it. The loss of water certainly isn't serious, and it does not seem to deteriorate the steel. When we cut into it there was no sign of corrosion or rust on the steel, and as far as we could see no evidence of deterioration at that point. I think that possibly cleaning down the outside of our standpipe at the present time might give a little better appearance, but I do not believe the commissioners feel they would be justified in going to any expense. In fact, we haven't had any expense during the five years the standpipe has been in use, and I don't think we should hesitate a moment about building another concrete standpipe.

Mr. Sanborn. — There is just one question I should like to ask Mr. Snell. If you should cut off the sun from the reservoir, would it be tight?

Mr. Snell. — I should think so, as it would keep the standpipe nearer an even temperature, judging from the concrete standpipe at Fort Revere, Boston Harbor, which is covered in and where there seems to be no seepage or leakage, and I believe it is due largely to that fact. We formerly had a steel standpipe, 30 ft. in diameter and 125 ft. high, and we had the same experience after emptying and filling that in regard to leaking. So that I presume there is more or less strain due to change of temperature and expansion and contraction caused by extreme

changes. On a dry day, either summer or winter, the stand-pipe will be almost perfectly tight, the leaks all stopped; then on a damp day, immediately afterwards you will get a pronounced seepage. So it seems the whole structure is governed largely by the temperature.

MR. CHARLES W. SHERMAN. — I think Mr. Andrews' theory is perhaps open to criticism upon one point, namely, his use of the formula for stress in a thin hollow cylinder when, as a matter of fact, the resulting thickness of the cylinder, especially near the base, is very considerable. The formula for stress in a thick hollow cylinder is something very different and not nearly as simple as the one used by Mr. Andrews. There can be no doubt that where the strength in the concrete is computed as taking a portion of the bursting stress, the variation in stress from the inside to the outside of the cylinder should also be considered. It will be found that the tensile stress near the inside of the cylinder is considerably greater than that near the outside.

MR. J. R. WORCESTER (*by letter*). — The method of proportioning reinforced concrete reservoirs proposed by the author has many elements of common-sense in it. It is based apparently upon the correct theory that if the stress induced by the water pressure is sufficient to stretch the wall beyond the tensile strength of the concrete and steel acting together, cracks are liable to be produced which may cause leaks. It would therefore seem to be one of the first principles of this class of construction to so proportion the parts that the tensile strength of the concrete shall not be exceeded. Moreover, the advantage gained by thickening the wall under this system of proportioning is undoubtedly of considerable value, as it tends to insure a better class of concrete, as well as to give the wall an inherent stability and make the water which is seeking for an outlet pass through a greater thickness of material in order to escape.

As to the units which the author has adopted in the case of the Rockland tank, there is some little question. If the tensile strength of the concrete were to be determined by the tests made in this instance, it would seem as if the allowed stress provided for a small factor of safety. In applying the results of these tests, the possible increase in strength of actual large sections over the test specimens of 25 per cent. is not clearly explained, and the writer, for one, would be glad to know by what process of reasoning the author considers such allowance permissible. The further addition of an increase of 10 per cent.

in strength on account of the presence of reinforcing rods does not accord with general practice, and is open to some question. Experimental proof of this property should be offered if any exists. On the other hand, it seems as if the results of the experiments were not as high as might have been expected on concrete of that richness two months old. In future construction, it would seem to be advisable to be a little more liberal with the factor of safety.

In the writer's experience, seepage through concrete reservoirs has been found to be almost exclusively confined to either horizontal joints or to bolt holes, used for clamping the forms together, which have been improperly filled. The vertical cracks which are described as being visible in the interior of reservoirs after the water has been drawn out can hardly be due to the cause ascribed, for stretch within the elastic limit of the metal would be so slight that the cracks could scarcely be visible even while the stress is maintained and must surely close up when the stress is removed, so as to be invisible. Moreover, a visible crack produced by the tensile stress would undoubtedly extend through the wall and cause a sheet of water to leak through. It seems more likely that these vertical cracks are only shrinkage cracks through the lining. The author speaks of the horizontal joints in the Rockland reservoir having been guarded against by means of a steel dam. It would be interesting for him to describe this a little more fully, if he will, and to state the result of the experiment. It is also to be hoped that he will inform the Society as to whether or not there is any evidence in the Rockland tank of vertical joints having been formed since the tank was filled.

Mr. Sanford E. Thompson (*by letter*). — The design of the Rockland reservoir is such a departure from previous methods of construction that a further word in regard to the methods of computation may be in order.

As the author of the paper has stated, the usual plan in the design of reinforced tanks or standpipes is to disregard the concrete except as a membrane for inbedding the steel and furnishing a curtain to hold the water. The steel is designed, on the other hand, to take all the tension due to the water pressure. In Mr. Andrews' design the special feature is the fact that the concrete is designed to take a part of the tension. This, while a departure from common practice, is not a departure from theories which have been proved and accepted.

When a combination of steel and the concrete in which it

is imbedded is pulled, as in the bottom of any reinforced concrete beam, they stretch together — provided the bars are small enough to give plenty of surface so as to prevent slipping — until the tensile strength of the concrete is reached. This is evidenced in numerous tests of beams made by various experimenters, which show conclusively that where the concrete adheres to the steel, the two act as one in the early part of the loading. In other words, these two materials stretch together, and as long as they are bonded together, they lengthen out uniformly. Now, from the principles of mechanics, within the elastic limits the stress equals the stretch in a unit length multiplied by the modulus of elasticity. Therefore, so long as the steel and the concrete stretch the same, on account of their bond, the *stress* in each material is inversely proportional to their modulus of elasticity and their area of section. Thus, if, at a certain load, the stress in the concrete is 284 lb. per sq. in., its stretch with modulus of elasticity $E = 3\,000\,000$, will be $\dfrac{284}{3\,000\,000} = 0.000095$ in. per inch of length. In like manner, the stress in the steel is the same stretch, 0.000095 in., times its modulus of elasticity, or since in steel, $E = 30\,000\,000$, the stress in steel is 30 000 000 times $0.000095 = 2\,850$ lb. per sq. in. This is irrespective of the areas of section of either the concrete or the steel.

The *strength*, however, is proportional to the areas, and hence if we have 423 sq. in. of concrete and 9.4 sq. in. of steel, the two together would resist (423 by 284) + (9.4 by 2 840) = 146 700 lb.

The theory is the same as in columns having vertical reinforcement.* The steel and the concrete act together in this way until the breaking strength of the concrete is reached, then the concrete breaks in a crack very fine at first, and the entire load is immediately given to the steel. It is evident, then, if we provide enough concrete so that its working strength in tension (together with the steel acting with it, as above) is not exceeded, no cracks should occur.

As a matter of fact, the reservoir, then, is designed like the tension side of a beam in the early stages of its loading before the minute cracks are formed. As a matter of safety, to be sure that the reservoir will not fail in case the concrete should crack from any unforeseen cause, enough steel is provided so

* See Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, page 489.

that, even if it has to take all the tension or pull, the stress in it will not exceed 16 000 lb. per sq. in. This is a higher allowable stress than is generally allowed in tank construction, because it is simply to guard against a contingency. In case it should be stressed to this amount, the reservoir would still be safe, although it would be apt to leak slightly at the point of crack. Under any conceivable conditions, therefore, it would appear that the reservoir would be safe.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 1, 1911, for publication in a subsequent number of the JOURNAL.]

# Association of Engineering Societies.

Vol. XLVI. JANUARY, 1911. No. 1.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, December 7, 1910. — The 694th meeting of the Engineers' Club of St. Louis was held in the Club Rooms, 3817 Olive Street, Wednesday, December 7, 1910. at 8.15 P.M., President Holman presiding. There were present 62 members and 5 visitors

The minutes of the 693d meeting of the Club were read and approved. The minutes of the 486th meeting of the Executive Committee were read.

It was moved by Mr. Humphreys, seconded by Mr. Flad, and carried, that the Club attend the funeral of Mr. Bryan in a body, and that a committee of three be appointed by the President to prepare resolutions in memory of Mr. Bryan. President Holman appointed Messrs. Humphreys, Flad and Russell.

The President announced that the joint meeting of the Club with the American Society of Mechanical Engineers for Saturday, December 10, had, out of respect for Mr. Bryan, been postponed subject to call.

The following gentlemen were elected to membership:

Members — Alten S. Miller, Chas. M. Hummel, Hugh E. Hale, Wm. D. Todd.

Associate member — John S. Bronson.

Junior member — Fred L. Bock.

An application for membership from E. R. Kinsey was read and referred to the Executive Committee.

The following reports were submitted and read:

1. Report of the Executive Committee, by Mr. M. L. Holman, chairman.
2. Report of the Secretary and Librarian, by Mr. W. W. Horner.
3. The Treasurer, Mr. C. M. Talbert, submitted a statement of the balance in the various funds and of the bank deposits, and announced that the full report would be ready on January 1, 1911.
4. Report of the Board of Managers of the Association of Engineering Societies, by Mr. John Hunter.
5. Report of the Meetings and Papers Committee, by Mr. E. L. Ohle.
6. Report of the Membership Committee, by Mr. E. E. Wall.
7. Report of the Entertainment Committee, by Mr. W. C. Zelle.

Mr. Greensfelder was called on for a report from the Committee on Quarters. He stated that the ventilating system had been installed and that the committee was waiting for the Academy of Science to sign a contract for electric power, so that the motor could be tested.

Mr. Von Maur reported for the committee authorized by the acceptance of the report of the Committee on "the Advisability of Withdrawing from the Association of Engineering Societies." It was moved by Mr. Philip N. Moore, seconded by Mr. Flad, that the report be printed and made a special order of business for the next meeting.

The Secretary read the list of officers for the ensuing year, named by the Nominating Committee. No other nominations were made.

Mr. Pitzman then spoke on "Some Points of Interest to Engineers in the Draft of the New Charter." A general discussion followed, participated in by Messrs. Aegerter, Greensfelder, Moore, Widmer, Henricks, Toensfeldt and Pitzman.

The meeting adjourned at 10 P.M. to the adjoining room, where the Entertainment Committee had provided a buffet luncheon.

W. W. HORNER, *Secretary.*

Boston Society of Civil Engineers.

SANITARY SECTION.

THE regular December meeting was held at the Boston City Club on Wednesday, December 7.

The resignation of Dr. Leonard P. Kinnicutt as vice-chairman of the Section was received and accepted with regret, and the Clerk directed to express to Dr. Kinnicutt in writing the thanks of the Section for the interest he has shown in its work. A nominating committee, consisting of Messrs. Chase, Johnson and Hall, was appointed to nominate a successor to Dr. Kinnicutt. They reported the nomination of Mr. George Bowers, who was unanimously elected to this office.

In accordance with notice received from Mr. S. E. Tinkham, Secretary of the main society, a committee of three was appointed, consisting of the Clerk, Messrs. Charles W. Sherman and Edward Wright, Jr., to report upon a revision of the by-laws of the Section to agree with recent changes in the constitution and by-laws of the main society.

The speaker of the evening was Mr. William B. Landreth, special deputy state engineer of New York, who for the last two years has been in direct charge of the New York State Barge Canal. Mr. Landreth took for his subject the New York State Barge Canal and illustrated his address by numerous lantern slides. Besides describing the general scheme for the new Erie and Champlain canals, and their method of water supply, Mr. Landreth took up various portions of the construction work now under way and described these somewhat in detail. Among the interesting features of this work are a great variety of methods of excavation, some very large and complex constructions of concrete in connection with the locks, the construction of several movable bridge dams on the Mohawk River, and numerous other novel features.

Mr. Landreth's paper was of great interest to the forty members of the Section who were present, and it was quite fully discussed.

At the conclusion of the discussion, the Section expressed its hearty thanks to Mr. Landreth for his interesting paper and for the time and trouble that he had taken to prepare it.

H. K. BARROWS, *Clerk.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., DECEMBER 12, 1910. — The eighth and last regular meeting of the year was called to order in the Society's quarters in Old State Capitol Building at 8.30 P.M., by President J. D. DuShane. There were present seven members and one visitor.

The minutes of the previous meeting were read and approved.

It was decided that the Society would have the customary banquet upon conclusion of business at twenty-eighth annual meeting, which will be held January 9, 1911. Oscar Claussen, H. J. Bernier and Oscar Palmer were appointed a committee to make all arrangements for banquet, and were directed to report such arrangement to the Governing Board of the Society for authorization as soon as possible.

The Secretary was directed to extend invitations to the banquet to the mayor of St. Paul, city engineers of St. Paul and Minneapolis, Governing Board of the Engineers' Club of Minneapolis, dean of the college of engineering of Minnesota State University, engineer for State Highway Commission, and Major Francis R. Shunk, Corps of Engineers, U. S. A.

The Secretary was directed to decline with thanks the offer of illustrated lecture on "The Panama Canal," by William M. Ridpath, made by the "Scorer Lyceum Bureau" of Philadelphia.

The resignation of Percy E. Barber was read. and the Secretary was instructed to advise Mr. Barber, "if he intended to move away from St. Paul, he was privileged to take advantage of the non-resident rate, and to ask him to kindly reconsider his resignation."

The petitions for full membership in the Society of Carlton B. Gibson, Harry C. Palmer and Robert Follansbee were then read. Upon motion duly seconded it was carried that the Secretary cast the ballot for the Society and elect the applicants as petitioned; they were declared elected.

There being no further business, the meeting adjourned.

D. F. JÜRGENSEN, *Secretary.*

ST. PAUL, MINN., JANUARY 9, 1911. The twenty-eighth annual meeting of the Civil Engineers' Society of St. Paul was called to order by President J. D. DuShane at 6.30 P.M. in *Parlor One* of the Ryan Hotel; there were present twenty-four members.

The minutes of the previous meeting were read and approved.

A communication from Mr. C. F. Loweth, chief engineer of the Chicago, Milwaukee & St. Paul Railway, and member of this Society, expressing sin-

cerest regrets at his inability to attend the twenty-eighth annual meeting and banquet, and wishing the Society a successful and prosperous New Year, was read and ordered filed.

The election of officers for the year 1911 was then held and resulted as follows:

L. P. Wolff, president; J. H. Armstrong, vice-president; D. F. Jürgensen, secretary; Oscar Palmer, treasurer and librarian; A. R. Starkey, representative on Board of Managers for the Association of Engineering Societies.

Upon conclusion of the election, President J. D. DuShane surrendered the chair to President-elect L. P. Wolff.

The annual reports of officers for the year 1910 were read, accepted and ordered filed.

Meeting then adjourned to banquet room, to enjoy the good-cheer the committee had there prepared, and which was participated in by thirty-one members and eight guests.

Ex-President J. D. DuShane acted as toastmaster: and spoke on the accomplishments of engineers during the year 1910.

Mr. Wm. R. Hoag, of the Engineers' Club of Minneapolis, responded on behalf of that club.

Mr. Oliver Crosby, of the St. Paul Society, told of the powers of gasoline when properly mixed with an admixture of air.

Hon. Adolph O. Eberhart, governor of Minnesota and honorary member of this Society, suggested that the state would be greatly benefited if it would employ more engineers to study and aid it in obtaining the most from its vast natural resources.

Hon. Herbert P. Keller, mayor of St. Paul, discussed various engineering problems from the viewpoint of an ordinary citizen.

Mr. Geo. W. Cooley, of the Engineers' Club of Minneapolis, and engineer for Minnesota State Highway Commission, described the roads of Europe, and declared the roads in the western states are superior to those in the eastern states.

Mr. Horace C. Stevens, of the St. Paul Society, told of his visit to the Panama Canal in 1898, while the French were still working there; he said the government could not have made a better bargain than it did.

Mr. Geo. A. Ralph, of the St. Paul Society, and engineer for State Drainage Commission, told of " The Civil Engineers' Opportunities in Minnesota."

Mr. Francis C. Shenehon, dean of the college of engineering of the Minnesota State University and ex-president of the Detroit Society, spoke of the training of young engineers at the university, and declared he would like to see the Engineers' Club of Minneapolis and the St. Paul Society join into one body and encourage the engineering students of the university to affiliate with such an organization as junior members, and stated further that in his judgment the students would be greatly benefited by association with practicing engineers.

The speakers engaged the attention and interest of banqueters until 11.30 P.M., when adjournment was taken by mutual consent.

D. F. Jürgensen, *Secretary.*

Montana Society of Engineers.

BUTTE, MONT., DECEMBER 10, 1910. — The December meeting of the Society was held at the usual place, date and hour. President Frank M. Smith presided. After the reading and approval of the minutes, the Secretary read the applications of Messrs. Sellers, Pratt, Kirk and Riddell for membership in the Society. Said applications were approved and the regular ballot ordered. George Arthur Packard was elected a member of the Society by a unanimous vote. President Smith named all the resident members in Helena of the Society as a committee of entertainment and arrangements for the twenty-fourth annual meeting, to be held in that city January 12, 13 and 14, 1911. Measures will be taken to provide all visiting members with hotel accommodations, which are not expected to be over-abundant at the Capital City next month.

Adjournment.

CLINTON H. MOORE, *Secretary.*

Utah Society of Engineers.

SALT LAKE CITY, DECEMBER 20, 1910. — On Saturday, November 26, 1910, the Utah Society of Engineers made an inspection of the lines of the interurban railways between Salt Lake City and Brigham City, Utah. Stops were made at Willard, Ogden Canyon, Lagoon and Brigham City to see power plants and substations. The trip was made in a special car chartered for the purpose, and luncheon was served at the Weber Club in Ogden.

The monthly meeting was held at the Commercial Club, Salt Lake City, on Tuesday, December 20, 1910. R. B. Ketchum, of the University of Utah, presented a paper upon "The Economic Design of Reinforced Concrete Beams and Slabs." Immediately preceding the meeting about sixty members of the Society and their friends were present at a "Get Acquainted Dinner," served in the Commercial Club's new building.

W. C. EBAUGH, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XLVI. FEBRUARY, 1911. NO. 2.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, DECEMBER 14, 1910. — The 695th meeting of the Engineers' Club of St. Louis, which was the annual dinner, was held at the Mercantile Club, Wednesday, December 14, 1910, at 7 P.M.

By special arrangement this meeting was made the first annual "Get-Together" dinner of the Engineers' Club and the local members of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers and the American Society of Engineering Contractors. There were 131 present, of whom the Honorables F. W. Lehman, F. W. Kreismann, B. J. Taussig, Maxime Reber and Dr. J. W. Robertson were guests of the Club.

After the dinner, President Holman announced the results for the election of officers and introduced Mr. Von Maur, the incoming President, to act as toastmaster. The following gentlemen were called upon:

Prof. Ernest O. Sweetser.... "The Student and the Engineer."
Hon. F. W. Lehman........ "The New Charter."
Hon. Maxime Reber........ "The Board of Public Improvements under the New Charter."
Mr. R. S. Colnon........... "The Engineer as a Contractor."
Mr. W. A. Layman......... "The 'Get-Together' Movement."

Dr. Robertson, of the Royal Industrial Training and Technical Education, was called upon informally and spoke at some length on the general subject of industrial education in Canada and the United States.

Professor Langsdorf moved a vote of thanks to the Entertainment Committee for the most successful banquet on record. This was unanimously carried.

Adjourned.

W. W. HORNER, *Secretary*.

ST. LOUIS, JANUARY 4, 1911. — The 696th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, January 4, at 8.30, President Von Maur presiding. There were present 37 members and 11 visitors.

The minutes of the 694th and 695th meetings of the Club were read and approved; the minutes of the 487th meeting of the Executive Committee were read.

Mr. E. R. Kinsey was elected to membership.

Applications for membership from the following were read and referred to the Executive Committee:

C. L. French, J. P. King, Patterson Bain, Jr., A. J. Robus, Hans Weichsel, Joe Underwood.

The Secretary read letters from Col. E. D. Meier and one from Charter Revision Conference. The latter was referred to the Executive Committee.

Mr. Wall moved that the report of the Committee "appointed to bring together the local members of the various national societies" be approved and that the Committee be continued and authorized to proceed with the negotiations with the other societies. Motion carried.

Mr. M. L. Byers, Chief Engineer of Maintenance of Way of the Missouri Pacific and Iron Mountain Railway companies, presented the paper of the evening on "An Analysis of Certain Relations between the Industrial Corporations and the Consumer."

The discussion was participated in by Messrs. Schuyler, Ohle, Wall, Langsdorf, Greensfelder, Von Maur, Childs, Timmerman and Byers.

Mr. Greensfelder moved a vote of thanks to Mr. Byers for his interesting paper and for the amount of discussion which it aroused.

Adjourned at 10.15.

W. W. Horner, *Secretary.*

St. Louis, January 18, 1911.—The 697th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, January 18, 1911.

By special arrangement this meeting was held as a joint meeting of the Club with the American Institute of Electrical Engineers, St. Louis Section.

The total attendance was 67, of whom 20 were members of the Engineers' Club, 18 of the American Institute of Electrical Engineers, 9 of both societies, and 20 were visitors.

President Von Maur called the meeting to order. The minutes of the 696th meeting of the Club were read and approved, and the minutes of the 488th meeting of the Executive Committee were read.

It was moved by Mr. Brenneke, seconded, and after some discussion carried without dissent, that the Engineers' Club of St. Louis should go on record as being in favor of the adoption of the New Charter for St. Louis.

President Von Maur then resigned the chair to Mr. Lamke, chairman of the American Institute of Electrical Engineers.

Mr. Joseph A. Osborn, electrical engineer for the American Car and Foundry Company, delivered an illustrated paper on "Motor Drive in the Steel Plant of the American Car and Foundry Company," which was followed by a general discussion.

Adjourned, 10.15 P.M.

W. W. Horner, *Secretary.*

Boston Society of Civil Engineers.

Boston, December 21, 1910. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock, P.M., President Henry F. Bryant in the chair, ninety-five members and visitors present.

It was voted to dispense with the reading of the record of the November meeting, and to approve the same as printed in the December *Bulletin*.

The President reported that the following had been elected to membership in the grades named:

Members — Messrs. Royall D. Bradbury, Harrison W. Hayward and William H. Lawrence.

Juniors — Messrs. Lawrence H. Allen and William H. Morrison, Jr.

A memoir of Edwin P. Dawley, late a member of the Society, prepared by past President George B. Francis, was presented and ordered to be printed in the Journal.

The President presented as the report of the Board of Government on the advisability of offering a prize for the best papers read before the Society, the following report prepared by a committee of the Board:

Boston, November 16, 1910.

To the Board of Government of the Boston Society of Civil Engineers:

The undersigned, the committee appointed by you to consider and report concerning the awarding of prizes for papers presented to the Boston Society of Civil Engineers, would respectfully report as follows:

This matter had its inception in the vote proposed by Mr. Desmond FitzGerald and adopted by the Society at its last annual meeting. Mr. FitzGerald has shown great interest in the subject, and has conferred several times with members of the committee. He has expressed the opinion that a bronze medal will be the best form for such a prize, his reasons being that the prize should be valued not for its intrinsic worth, but solely as a testimonial that the holder of it has contributed something which his fellow-members consider of great value to the engineering profession; also that the evidence of having received such an award will be more available and less likely to be deposited where it can seldom be seen if the medal is of bronze rather than of a precious metal.

Mr. FitzGerald has very generously offered to provide for the preparation of suitable dies for the medal if the Society decides upon that form of a prize and to provide a sufficient fund for the furnishing of the medals in perpetuity. Your Board has practically adopted his suggestion by voting to accept the gift, and in consideration of this offer and of the many other services by Mr. FitzGerald to the Society in the past has also voted to call the prize "The Desmond FitzGerald Medal."

The only other matter which we, as a committee, have to consider, is the method of the award. After studying the rules of the American Society of Civil Engineers for the award of prizes, we think that those rules will be perfectly adapted to our case with only such changes of names and dates as are necessary to adapt them to our conditions.

We, therefore, submit the following as a form of statement concerning the prize and a code of rules for its award.

Rules Governing the Award of the Desmond FitzGerald Medal.

There is at present one endowed prize for papers published by the Boston Society of Civil Engineers. This prize is to be awarded annually unless the Board of Government shall decide that none of the papers presented during the year are of such a character as to merit the award.

With the assent and approval of the donor, the Society assumes the responsibility for the payment in perpetuity of the Desmond FitzGerald Medal.

Committee on Award.

1. The Board of Government shall appoint annually, not later than its regular meeting in June of each year, three members of the Society, not members of the Board of Government, who shall form a committee to recommend the award of the prize.

2. The papers considered shall include all papers published by the Society during the year ending with the month of September.

3. The Committee on Award shall report its recommendation to the Board of Government on or before March 1, and the awards shall be made by the Board of Government.

4. The announcement of the awards shall be made at the annual meeting.

5. The Secretary of the Society shall act as secretary to the Committee on Award, but shall have no vote or voice in its deliberations.

Code of Rules.

The Desmond FitzGerald Medal. — This medal was instituted and endowed in 1910 by Desmond FitzGerald, member and past president of the Boston Society of Civil Engineers.

I. Competition for the medal of the Boston Society of Civil Engineers shall be restricted to members of the Society of all grades.

II. There shall be one bronze medal awarded as hereinafter provided. The dies therefor shall be deposited with the superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose.

III. All original papers presented to the Society by members of any class, and published by the Society during the year for which the medal is awarded, shall be open to the award, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society.

IV. The medal shall be awarded for a paper which shall be judged worthy of special commendation for its merit.

As Mr. FitzGerald desires to be consulted as to the design of the medal, we would recommend that, with his consent, that matter be referred to him.

Respectfully submitted,

Edward W. Howe,
J. R. Worcester,
Geo. B. Francis,
Committee.

On motion of Mr. Howe it was voted to accept the report and adopt the rules and recommendations contained therein and to confirm the action of the Board in accepting the gift and naming the medal for its donor.

The thanks of the Society were voted to Mr. Patrick McGovern and to Coleman Brothers for courtesies extended to members of the Society this afternoon on the occasion of the visit to the work now in progress on the Beacon Hill tunnel.

The Secretary presented and read by title a paper by Charles H. Dutton, a member of the Society, entitled "The Design of Eccentrically Loaded Concrete Members Reinforced on One Face Only."

Mr. H. B. Andrews, engineer for Simpson Brothers Corporation, Boston, was then introduced and read a paper entitled, "A New Theory for Reinforced Concrete Reservoirs."

The paper was discussed by Messrs. R. C. Allen, L. C. Wason, A. B. MacMillan, Bertram Brewer, F. A. Barbour and others, the lantern being freely used to illustrate the original paper and the discussions.

After passing a vote of thanks to Mr. Andrews for his very interesting paper, the meeting adjourned.

S. E. Tinkham, *Secretary.*

A special meeting of the Sanitary Section, Boston Society of Civil Engineers, was held at the Boston City Club on Wednesday evening, December 28, 1910.

The speaker of the evening was Mr. Charles Saville, late assistant engineer of the Massachusetts State Board of Health, and at the present time assistant engineer of the Sewerage Department of the Emscher-Genossenschaft, Essen, Germany.

Mr. Saville described considerably in detail and in a very interesting manner the comprehensive work of sewerage and drainage that is being carried on in this district of Germany tributary to the Emscher River.

In the treatment of sewage the method employed is to use the Imhoff subsidence or clarification tank, which removes the suspended solids automatically and continuously, and at the same time provides for the complete decomposition of the solid matter in a septic chamber in the lower part of the tank, the contents of which are not allowed to come in contact with the sewage flowing through the upper or sedimentation chamber. The other important feature in this method of sewage treatment consists in getting the sewage out of the cities and towns and into the river channels as soon as possible. This is being effected by reconstructing the whole system of channels with concrete linings so that the velocity of flow is very rapid and smooth. This work was begun in 1904 and will be completed in perhaps another year, and the final effectiveness of this method of treatment will not be certainly known until after that time.

Mr. Saville illustrated his remarks by the use of diagrams and lantern slides, and his paper was discussed by Messrs. Stephen De M. Gage, H. P. Eddy, E. B. Phelps and others. A written discussion from Mr. George W. Fuller of New York City was also received and read.

About sixty members of the Section, with guests, were present, and at the close of the meeting the thanks of the Section were expressed to Mr. Saville for his very clear and interesting description of this new and important work.

Mr. Saville returns to Germany at once, and the Section is much indebted to him for spending a considerable portion of his very brief vacation in this manner.

H. K. Barrows, *Clerk.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., February 13, 1911. — The second regular meeting of the year was called to order in the Society's quarters in the Old State Capitol Building, by President L. P. Wolff, at 8.30 o'clock P.M. There were present 15 members and 1 junior.

The minutes of the previous meeting were read and approved.

A communication from Walter W. Curtis, a trustee of the Western Society of Engineers, inviting our Society to affiliate with the Western Society was read; upon motion duly carried the Secretary was directed to communicate further with Mr. Curtis and ascertain from him more details and particulars in connection therewith.

The following resolution concerning the matter of state appropriations for the continuation of surveys and investigations of the engineering depart-

ment of the State Drainage Commission relative to the water resources of the state was unanimously adopted, and the Secretary was directed to send a copy of same to the president of the senate, speaker of the house of representatives, and to the chairman of both the committees of the senate and house having this matter in hand.

Resolution.

Whereas, the waters of the state form one of its most important resources in connection with the generation of power, municipal water supply, sewerage disposal, and in an uncontrolled condition are a menace to property in many sections of the state; and

Whereas, preliminary investigation made by the State Drainage Commission working in coöperation with the United States Geological Survey has indicated the magnitude of these resources and has resulted in acquiring preliminary data of very great importance in utilizing these resources; and

Whereas, the extremely low flow of 1910 has shown the great need for future accurate determination of the flow of the rivers in order to utilize them intelligently and in a manner that will not be a menace to the public health; and

Whereas, on account of the variable flow of the rivers from year to year, it is necessary to extend the investigation over a series of years; and

Whereas, the Federal Government has placed at the disposal of the state the efficient organization of the United States Geological Survey, and is prepared to coöperate with the state so far as federal appropriations admit; and

Whereas, we, the members of the Civil Engineers' Society of St. Paul, fully realize the great benefits that will accrue to the state through the continuation of the water resources investigations which will result in the more speedy and more efficient utilization of these resources,

Be it resolved, that the continuation of the water resources investigations of Minnesota constitutes an important duty devolving upon the state, and that in the discharge of that duty an annual appropriation of not less than $15 000 be made, as recommended by the State Drainage Commission in order to carry on in coöperation with the Federal Government the investigations already undertaken and to extend these investigations, to the end that the necessary information may be had for utilizing one of the greatest of the state's resources to its fullest extent, and in such a manner as to prevent future damage from it in an uncontrolled condition. This constitutes conservation in its truest sense.

Be it further resolved, that a copy of these resolutions be brought to the attention of the proper officials of the state legislature.

The following resolution relating to state appropriations for the engineering department of State Board of Health was introduced, and upon motion, which prevailed, was placed in the hands of a committee consisting of Messrs. Wolff, Claussen, Starkey, Danforth and Jürgensen, for further investigation and consideration, with full power to act.

Resolution.

Whereas, the Engineering division of the State Board of Health has been in existence for five years and has demonstrated its usefulness to the cities and villages of Minnesota as similar engineering divisions have in other states; and

Whereas, it has collected the latest and best information on the subject of sewage and water purification by personal inspection and by comprehensive and thorough studies and examinations in various parts of the United States and Europe; and

Whereas, the results of these studies, examinations and observations are available to all cities and villages and engineers; and

Whereas, the Engineering Division of the State Board of Health has been instrumental in saving lives by its efforts to secure a proper and wholesome water supply and sewer and water purification, and in saving money by suggesting improved methods of construction; and

Whereas, the most advanced states of the Union place large appropriations at the disposal of their boards of health for engineering matters in connection with water supply and sewerage installations; and

Whereas, we, the members of the Civil Engineers' Society of St. Paul, fully realize the benefits that will accrue to the state through the continuation of a liberal policy in assisting the efforts of the State Board of Health along the lines above expressed,

Now, therefore, be it resolved, that the Engineering Division of the State Board of Health is worthy of more generous support by greatly increased appropriations and that said appropriations should be not less than $25,000 per year; and

Be it further resolved, that a copy of these resolutions be brought before the proper officials of the state legislature.

For the purpose of obtaining an expression from our members, a general discussion was invited, on the suggestion of Francis C. Shenehon, dean of the College of Engineering of Minnesota State University, viz., that our Society consolidate with the Engineers' Club of Minneapolis and form one large *Twin City Organization*, and take in as junior members the engineering students of the university. It was the sense of the meeting that such students could now affiliate with our Society if they so desired, and that we remain as we now are.

A request for an exchange of club house and library privileges from Secretary Gearhart, of the newly organized Kansas Engineering Society of Manhattan, Kan., was read; on motion which prevailed, these privileges were granted.

The resignation of Percy E. Barber as a member of the Society was read and accepted.

The Examining Board for 1911 was then appointed, and consists of Messrs. Armstrong (chairman), Du Shane and Palmer.

The Librarian was authorized to formulate such rules as will be expedient and proper for the administration of the books and other matter contained in the library and to provide each member with a copy thereof, and was directed to display said rules in a conspicuous place in the library.

The Librarian was directed to have fire insurance to the amount of $1 000 placed upon the Society's books, bookcases and office furniture.

Upon motion, duly carried, the President was directed to appoint a Public Affairs Committee, consisting of five members, whose duty shall be to observe, investigate and report all matters of special interest to the engineering profession to the Society with recommendations.

The following compose the above said committee: Messrs. Wolff (chairman), Claussen, Ralph, Dugan, Rathjens.

The chairman was directed to appoint a Membership Committee consisting of three members, whose duty shall be to make a special and consistent effort to secure members.

The following compose the said committee: Messrs. Bernier (chairman), Chas. D. Batson and A. F. Meyer.

A general discussion of engineering matters then followed until adjournment was taken at 11 o'clock P.M.

D. F. JÜRGENSEN, *Secretary*.

Montana Society of Engineers.

Helena, Montana, January 12, 13, 14, 1911. — Thursday was not a very bad day. There have been worse. There was no delay in railway transit; the cars were unusually comfortable. Promises of attendance gave evidence of much interest, strong desire and professional enthusiasm. Some people began to make promises soon after birth and have kept up the habit ever since. They do not mean anything bad. They do not think that on their promises are laid the plans of annual meetings and kindred gatherings, and on their promises realizations of success depend. However, a large number of promises were redeemed on the borders of "Last Chance." Comfortable quarters were furnished the visitors by a faithful committee of arrangements, and all went merry as was a newly married couple on their way to Glengarry.

Friday. As soon as inward fortifications against frost and cold were completed, the visiting members were taken in charge by the Helena contingent and escorted to East Helena, where they were allowed an inspection of the works of the A. S. & R. Co., having for guides the general manager and superintendents. The various improved methods and machinery were fully explained, and generous hospitality dispensed. After a comfortable return to the city a few political aspirants for senatorial honors visited the State Capitol building and solicited recognition from the Solons there assembled. They didn't get any — not a taste. In the afternoon all the members who wished, and the wishers were in the majority, were taken in autos to the site of the Hauser Lake dam, some eighteen miles from Helena. The work in progress was fully explained and examined, the temperature of the locality thoroughly tested and a regretful farewell said to the construction engineers and force. In the evening an hour was given to pleasure and art at the Family Theater. There grace and beauty rivaled each other on the mimic stage, and tragedy wept while comedy smiled. In order to quell the emotions of the auditors, an adjournment was had to the Montana Club where music rose with not so voluptuous a swell after all. The new psalm book was brought into action, and afforded relief to the arduous trials of a happy day.

Saturday. The business session of the Society was called to order in the rooms of the Commercial Club, Pittsburg Block, at 10 A.M., President Frank M. Smith in the chair. Thirty-six members were present. The minutes of the December meeting were read and approved. The Secretary presented applications for membership in the Society from Messrs. George Doyle Curtis, James Hill Kyd and Peter Simonson Hervin. These applications were approved and the regular ballots ordered. Messrs. Pratt, Riddell, Sellers and Kirk were elected to membership. The ballots for the officers for the ensuing year were then counted, Messrs. Kemper and Jones being appointed tellers by the chair. The ballot was unanimous in favor of all the candidates, and President Smith declared the officers elected for the year 1911, to wit: President, Fredk. W. C. Whyte; First Vice-President, Robt. A. McArthur; Second Vice-President, John H. Klepinger; Secretary and Librarian, Clinton H. Moore; Treasurer and Member of the Board of Managers of the Association of Engineering Societies, Samuel Barker, Jr.; Trustee for three years, Willis T. Burns. President Smith presented President-elect Whyte, who took the chair. The report of the Secretary was read and approved. The Secretary explained the absence of the Treasurer's report, and stated he had checked the accounts with the Treasurer and that their records agreed. The chairman

presented the report of the State Road Committee, which, on motion, was adopted and the committee continued for another year. Letters were read from H. J. Horn, Jr., and E. Tappan Tannatt, and the Secretary was instructed to send explanatory letters in reply. An application for membership from Howard Noble Stockett was read, approved and ballot ordered. At this juncture the question of a change in the date of holding the annual meetings of the Society was considered, and after considerable favorable discussion it was decided by vote that it was the sense of the members present that the annual meetings should be held on the second Saturday in April of each year, beginning with April, 1912, and that the Secretary should prepare the necessary amendments to the Constitution of the Society for the March meeting. On motion it was voted that the salary of the Secretary for the coming year be $150, that his expenses to annual meetings be paid, including the present meeting. A recess was taken till 2 P.M.

The afternoon session was devoted to exercises of a literary character. The addresss of the retiring President, Frank M. Smith, was presented by its author, and contained a large fund of valuable information. Mr. Wm. L. Miller gave an interesting talk on the reconstruction work of the Hauser Lake dam. His remarks were supplemented by Mr. E. S. Jarrett, who is in charge of the caisson work of the dam. After a short recess Mr. C. W. Goodale told his fellow-members of his recent visit to the Panama Canal, a subject of great interest to all present, and the remarks contained many things not disclosed to the general public along engineering lines. All the talks and addresses received many favorable comments. The President referred back to the order of business, admission of candidates, and the Secretary presented the applications of Messrs. Robt. McIntyre, L. S. Williamson and H. E. Fearnall for membership, and after approval the ballots were ordered. The thanks of the Society were voted to all who had contributed to the success of its twenty-fourth annual meeting, after which adjournment followed. The regular banquet followed.

CLINTON H. MOORE, *Secretary.*

# ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XLVI. MARCH, 1911. NO. 3.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, FEBRUARY 1, 1911. — The 698th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, on Wednesday evening, February 1, at 8.15 o'clock, President Von Maur presiding.

There were present 33 members and 7 visitors.

The minutes of the 697th meeting were read and approved and the minutes of the 488th meeting of the Executive Committee were read.

The following were elected to membership in the Club: J. P. King, C. L. French, Joe Underwood, A. J. Robus, Hans Weichsel, Patterson Bain, Jr.

Applications for membership were read from the following:

Members — F. Y. Parker, E. C. Constance, J. E. Conzelman, F. C. Harper, J. E. Hillemeyer.

Juniors — W. R. Crecelius, A. H. Baum, Jr

The following committee appointments were announced:

Membership Committee — Richard L. Miller, chairman; H. I. Finch, H. H. Humphreys, J. A. Hooke, M. L. Byers.

Entertainment Committee — E. D. Smith, chairman; S. B. Way, W. H. Henby, H. E. Hale, D. McArthur.

Mr. W. S. Henry was appointed the third member of the Meetings and Papers Committee.

The meeting was notified of the death of Oddgeir Stephenson. The President appointed Messrs. Langsdorf, Lamke and Ohle as a committee to draft resolutions of sympathy.

Professor Langsdorf for the Executive Committee introduced the following amendment to Articles III and IV of the Constitution. The articles to be amended so as to read:

ARTICLE III, SECTION 1. — The officers of the Club shall be a President, a *first* Vice-President, a *second Vice-President*, a Secretary, a Treasurer, a Librarian and two Directors, who shall be chosen by ballot in the month of December of each year, and shall hold their offices for one year, or until their successors are duly elected. Vacancies shall be filled at the first meeting after they occur.

Balloting for officers shall be conducted in such a manner as shall be prescribed in the By-Laws.

SECT. 2. — The duties of the President, the *two* Vice-Presidents, Secretary and Treasurer shall be such as are customary for such officers and such as shall be prescribed by the By-Laws, etc.

ARTICLE IV, SECTION 1. — The President, *the two* Vice-Presidents, *the* Secretary, *the Treasurer* and the two Directors shall constitute an Executive Committee, whose duty it shall be to consider and recommend plans for promoting the objects of the Club; to audit all bills against the Club, and direct payment of such as they shall approve; to consider all applications for membership; and generally to administer the business of the Club subject to the Constitution and By-Laws, and to such instruction as may be given them by the Club from time to time.

SECT. 2. — No action of the Executive Committee shall be taken except upon the affirmative vote of *four* of its members. All doings of the Executive Committee shall be reported to the Club and entered upon its records.

Professor Langsdorf moved that the meeting recommend the amendment to the Club for letter ballot. Motion seconded and carried without dissent.

Professor Langsdorf presented the following amendment to the By-Laws. Section 2 of the By-Laws to be amended so as to read as follows:

BY-LAWS, SECTION 2. — *Dues.* The initiation fee for Members and Associate Members shall be $10.00; for Juniors, $3.00. On promotion to the grade of Member or Associate Member, Juniors shall pay an additional initiation fee of $7.00. *But the initiation fee shall be waived in the case of applicants who, at the time of their application, shall be members in good standing, and in any grade of membership, of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers or the American Society of Mining Engineers.* Etc.

Mr. E. H. Tenney, assistant to the chief engineer of the Union Electric Light and Power Company, presented the paper of the evening on "Economic Generation in Central Station Plants."

The discussion which followed was participated in by Messrs. Ohle, Flad, Humphrey, Hunter, Bausch, Johns and Tenney.

Adjourned at 10.15 P.M.

W. W. HORNER, *Secretary.*

ST. LOUIS, FEBRUARY 15, 1911. — The 699th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, on Wednesday, February 15, at 8.30 P.M., President Von Maur presiding. There were present 42 members and 6 visitors.

The minutes of the 698th meeting of the Club were read and approved; the minutes of the 489th and 490th meetings of the Executive Committee were read.

The following were elected to membership:

Members — F. Y. Parker, E. C. Constance, J. E. Conzelman, F. C. Harper, J. E. Hillemeyer.

Juniors — W. R. Creeelins, A. H. Baum, Jr.

Applications for membership from the following were read: F. C. Bagby, T. D. Budd, J. W. Stjernstedt.

It was moved by Mr. Talbert, seconded and carried, that the President appoint a committee to consider the proposed schedule of charges for professional services of consulting and construction engineers.

Mr. Zelle moved that the President appoint a committee to confer with the Committee of the American Institute of Architects with reference to the

proposed state law providing for the licensing and regulating of the practice of architects; and to recommend to the Club what action should be taken on the matter. So voted.

Mr. A. O. Cunningham, chief engineer of the Wabash Railroad, presented a paper on "Strengthening the Columns of the Approaches of the St. Charles Bridge." The approaches were steel trestles with round columns about 6 in. in diameter. In strengthening these columns they were encased in concrete reinforced with a spiral hooping, the outside dimensions of the concrete columns being about 18 in. Several views of the work and curves, showing the result of tests on similar columns, were shown on the screen.

Adjourned at 10.20.

W. W. Horner, *Secretary*.

The President subsequently appointed on the first committee, W. G. Brenneke, chairman; H. J. Pfeifer, Carl Gayler. On the second committee, Edw. Flad, chairman; Geo. Evans, J. W. Woermann.

St. Louis, March 1, 1911. — The 700th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, on Wednesday, March 1, 1911, at 8.15 P.M., President Von Maur presiding. There were present 45 members and 8 visitors.

The minutes of the 699th meeting of the Engineers' Club were read and approved; the minutes of the 491st meeting of the Executive Committee were read.

Messrs. J. W. Stjernstedt, F. C. Bagby, T. D. Budd were elected to membership, and an application for membership was read from Mr. M. C. Byers.

A letter was read from the Secretary of the St. Louis Association of the American Society of Civil Engineers announcing that the association had unanimously voted to accept the proposition of the Club for coöperation and joint meetings.

A letter from the St. Louis section of the American Society of Engineering Contractors, asking for affiliation with the Club on the same terms as submitted to the other national societies, was read and referred to the Committee on "Wider Organization" (Mr. Von Maur, chairman).

Mr. J. C. Travilla, street commissioner, presented the paper of the evening on "Theory and Practice in a Municipal Department." Mr. Travilla described briefly the work of the street department of St. Louis, and in detail the construction of oiled roads, illustrating with about forty slides of sections of road and photographs of the machines used and of the progress of the work.

Mr. Pfeifer moved that the Club extend a vote of thanks to Mr. Travilla and that the paper be published in the Journal. So voted.

Adjourned 10 P.M.

W. W. Horner, *Secretary*.

Boston Society of Civil Engineers.

Boston, January 25, 1911. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President Henry F. Bryant in the chair, ninety-five members and visitors present.

It was voted to dispense with the reading of the record of the December meeting and to approve the same as printed in the January *Bulletin*.

The President reported that the following had been elected to membership in the grades named:

Members — Messrs. Harold O. Butler, Ivan A. F. Chisholm, James T. Frame and Fred W. Lang.

Juniors — Messrs. Conrad Nolan and Lawrence G. Rice.

The President stated that it was proposed to hold a meeting on April 5, 1911, to which the students in civil engineering at the Institute of Technology, at Harvard University and at Tufts College would be invited to be present as guests of the Society.

On motion of Mr. Winslow, the President was requested to appoint a committee of three to report to this meeting the names of five members to serve as a committee to nominate officers for the ensuing year. The President appointed Messrs. E. W. Howe, A. H. Howland and J. N. Ferguson as the committee. This committee reported later in the meeting the following names, and by vote of the Society they were chosen as the Nominating Committee, — Richard A. Hale, Harold K. Barrows, George D. Emerson, Frank B. Sanborn and Sturgis H. Thorndike.

The President reported for the Board of Government that it had voted that the annual meeting this year and other functions connected with it would be similar to those of last year.

The Secretary read a communication from the United Improvement Association of Boston in relation to legislation providing for the building of ten miles of sidewalk each year in the suburban districts of Boston. The Association asked that action be taken by the Society on a proposed bill having this end in view. The President stated that the Board of Government had considered the matter, and, inasmuch as a large percentage of our members were not citizens of Boston, recommended that it was inexpedient for the Society to act in the matter. On motion of Mr. French, the recommendation of the Board was adopted.

A letter from Past President George B. Francis was read in relation to proposed legislation providing for the licensing of civil engineers in the various states, and enclosing a copy of the action taken by the American Society of Civil Engineers on the subject.

Mr. Sherman presented the following resolutions prepared by the Board of Government and moved that they be adopted by the Society.

Whereas, laws requiring the licensing of engineers have been suggested in the legislatures of several states; and

Whereas, the membership of the Boston Society of Civil Engineers is scattered over practically the whole United States and the practice of its members is still more widely diversified; and

Whereas, there are societies of engineers in the United States membership in which can only be secured after rigid examination of the fitness of applicants to practice as engineers; and

Whereas, the public has ample protection if they will employ only those who have thus demonstrated their ability; be it

Resolved, that the Boston Society of Civil Engineers does not deem it necessary or desirable that engineers should be licensed in any state.

By a unanimous vote the Society adopted the resolutions.

Memoirs of Past President George L. Vose, prepared by Profs. Alfred E. Burton and George F. Swain, and of William Jackson, prepared by Messrs. Desmond FitzGerald, E. D. Leavitt and F. H. Fay, were presented and ordered printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

On motion of Professor Moore, the thanks of the Society were voted to the officials of the Boston Elevated Railway Company, and to Mr. H. P. Nawn, president of Hugh Nawn Contracting Company, for courtesies extended to members on the occasion of the visit to the Cambridge Main Street Subway this afternoon.

The speaker of the evening, Lieut. Frederic R. Harris, civil engineer, United States Navy, was then introduced and gave a very interesting lecture entitled "Dry Docks and Dry Dock Construction and a Description of the Construction of Dry Dock No. 4 at the Brooklyn Navy Yard."

Mr. J. W. Rollins, president of the Holbrook, Cabot & Rollins Corporation, the contractors for the work, followed with an account of the plant and the method of construction at the Brooklyn Dry Dock. The lantern was used by both speakers to illustrate their remarks.

At the close of the discussion which followed, the thanks of the Society were voted to Lieutenant Harris for his interesting paper. Adjourned.

S. E. TINKHAM, *Secretary*.

BOSTON, FEBRUARY 15, 1911. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., Vice-President Charles T. Main in the chair, sixty-five members and visitors present.

The record of the last meeting was read and approved.

The Secretary reported for the Board of Government that the following candidates had been elected to membership in the grades named:

Members — Messrs. James A. McMurry, John E. Palmer and John J. Oakes.

Junior — Mr. Maurice B. Greenough.

The Secretary also reported for the Board that it had been voted to recommend to the Society that a sum not exceeding five hundred dollars be transferred from the Permanent Fund to the Current Fund to meet the deficit in the latter fund at the close of the current year. Mr. Winslow moved that a sum not exceeding five hundred dollars be appropriated from the Permanent Fund, as recommended by the Board of Government. After a discussion by Mr. Howe, the Secretary and others, a vote was taken and the motion declared lost, 22 in favor and 15 against, not the necessary two thirds.

The chair announced the deaths of the following members of the Society:

Burton I. Drisko, died January 8, 1911; Joseph R. Carr, died January 27, 1911; Louis E. Hawes, died January 29, 1911; Leonard P. Kinnicutt, died February 6, 1911.

By vote the President was requested to appoint committees to prepare

memoirs of the deceased members named. The committees appointed are as follows:

On memoir of Mr. Drisko, Mr. L. L. Street; on memoir of Mr. Carr, Mr. W. E. McClintock; on memoir of Professor Kinnicutt, Messrs. H. P. Eddy and C.-E. A. Winslow; and on memoir of Mr. Hawes, Messrs. George M. Warren and Erastus Worthington.

On motion of Mr. Higgins, the thanks of the Society were voted to Mr. Orlando W. Norcross for courtesies extended to its members on the occasion of the visit to the foundation work now going on at the Boston Custom House this afternoon.

Mr. Walter McCulloh, consulting engineer, New York State Water Supply, who had accepted an invitation to address the Society at this meeting and had come to Boston for the purpose, was forced at the last moment to remain at his hotel by advice of his physician. Prof. H. K. Barrows kindly consented to read Mr. McCulloh's paper, which was entitled "Water Resources of the State of New York," and to describe the lantern slides which accompanied the paper.

The Society was very fortunate in having Professor Barrows as a substitute for the speaker of the evening because of his familiarity with the territory covered by the paper.

The paper was discussed by Vice-President Main, Professor Barrows and others.

The thanks of the Society were voted, unanimously, to Mr. McCulloh for his very interesting paper and the Secretary was directed to express to him the sympathy of the Society and its sincere hope for his speedy recovery.

S. E. Tinkham, *Secretary.*

Boston, March 15, 1911. — The annual meeting of the Boston Society of Civil Engineers was held at the Boston City Club, 9 Beacon Street, at 12.30 o'clock P.M., President Henry F. Bryant in the chair.

The reading of the record of the last meeting was dispensed with and it was approved as printed in the March *Bulletin*.

The Secretary reported, for the Board of Government, that the following candidates had been elected to membership in the grades named:

Members — Messrs. Benjamin F. Bates, Carl C. Harris and Alfred E. Haskell.

Junior — Mr. Samuel Schwartz.

The Secretary read his annual report and by vote it was accepted and placed on file.

The Treasurer read his annual report and by vote it was accepted and ordered printed in the *Bulletin*.

Mr. Hale, for the Committee on Excursions, read its annual report, and by vote it was accepted and ordered printed in the *Bulletin*.

The Librarian read the annual report of the Committee on the Library and by vote it was accepted and ordered printed in the *Bulletin*.

The Secretary read the annual report of the Board of Government and by vote it was accepted and ordered printed in the *Bulletin*.

Mr. Cowles, for the Society members of the Joint Committee on Clubhouse, made a verbal report, and Professor Hollis, chairman of the Joint Committee, reported progress, saying in part as follows:

The Committee appointed one year ago to consider the suggestions of Mr. Francis that a building be obtained or erected for bringing together under one roof all of the Engineering Societies in Boston has met at intervals since its formation. The committee has consisted of men representing the Boston Society of Civil Engineers, the American Institute of Electrical Engineers, the American Society of Mechanical Engineers, the American Institute of Architects, the New England Section of the Illuminating Engineering Society, the New England Section of the National Electric Light Association, the New England Association of Gas Engineers, New England Water Works Association, the Northeastern Section of the American Chemical Society, the New England Section of the Society of Chemical Industry, the Telephone Society of New England. Subsequently, representatives from the New England Street Railway Club, the New England Railroad Club, the National Association of Cotton Manufacturers and the Massachusetts Highway Association were present. There have been about twenty on the committee, three of whom have been representatives of the Boston Society of Civil Engineers.

The discussion and investigation during the year have related principally to the best locality for the engineering building. A number of locations have been examined with reference to availablity, convenience and cost. It has, in general, been found that where the cost of location and proposed building were high, the returns in rentals promised to be proportionately high; and that where the cost of the location and building were low, the returns were likewise low. Hence, so far as the actual financing of an engineering building has been considered, it has made little difference about the location.

A circular was sent out to all engineers and others, describing the plans and requesting the names of men who approved the formation of an engineers' club to have a home in the proposed building. From four thousand circulars sent out, between five hundred and six hundred replies were received expressing approval and a wish to join an engineers' club.

The plans, as a whole, contemplated a home for the engineering profession and for other professions of applied science that have some interest in an alliance with engineering. There were to be auditoriums for the meetings of societies, a technical library, rooms for an engineers' club, and space on the ground floor for commercial purposes, so that some return might be received in the nature of rents. After a year's discussion and examination of the subject, the committee has finally agreed upon a definite locality facing the Public Gardens, and it only remains to finance the project. It will be necessary, in order to do this, to appoint a Board of Trustees consisting of representative men not exceeding five in number, to take the responsibility for carrying the undertaking through and to be able to speak for its soundness.

It is also proposed to have a smaller working committee under the general committee appointed last year, for the purpose of developing plans and devising methods for getting the money necessary for the construction or purchase of buildings. The location facing the Public Gardens, which seems to answer all purposes, would involve the making over of a building already constructed into a club house, and the construction of one additional building. The cost would be, including the real estate, about $700,000.

The matter will be placed in the hands of an agent to work out the financial statement, and it is already in the hands of an architect who is working on a definite plan.

It seems to the committee that enough pioneer work has been done in regard to location, and that the engineers ought to proceed with all the vigor and enthusiasm that can be found in the societies to raise the money for this project. With the sum stated above, the interest and taxes would be in the neighborhood of $40,000 to $45,000 a year. Enough rentals can probably be obtained in return to cut the actual outlay down to something between $20,000 and $25,000 a year, so that a club of engineers and others would have to provide this sum in addition to the running expenses of the club.

With 1,000 active members and an equal number of non-resident members, a sufficient return per year can easily be provided, and it only remains for the committee having the matter in charge to work out a definite statement in writing, together with the drawings, and then to place the entire project before the engineering profession here.

One of the methods of financing the undertaking would be a mortgage

and stock taken by friends. It is not intended here to go into details, but to suggest to the Boston Society of Civil Engineers the method by which we can all obtain a home in Boston, and to ask the help and coöperation of this Society in carrying it out. The Boston Society is more interested than any other scientific society in Boston, as they have canvassed the question of a building for many years and they ought now to be the leaders in bringing it to a successful outcome. A definite report will be submitted as early as possible, showing a fairly accurate estimate of the cost.

It has not been finally decided how the trustees should be appointed, but it will be difficult to think of a body of five trustees without having the local Society of Civil Engineers fully represented.

Both reports were accepted and placed on file.

The Secretary read a cablegram conveying the greetings of the following members of the Society, who were on their way to Panama: C. T. Main, J. W. Rollins, G. A. Carpenter, F. W. Dean, Dexter Brackett, H. P. Eddy, S. K. Clapp, C. R. Main, W. O. Wellington and T. T. H. Harwood.

The tellers of election, appointed by the President, Messrs. H. A. Varney and David Sutton, submitted their report giving the result of the letter ballot. In accordance with the report, the President announced that the following officers had been elected:

President — Charles T. Main.

Vice-President (for two years) — Frederic H. Fay.

Secretary — S. Everett Tinkham.

Treasurer — Charles W. Sherman.

Directors (for two years) — Charles R. Gow and L. Lee Street.

The recommendation of the Board of Government, that the vote passed at the last annual meeting instructing the Secretary to prepare a certificate of membership be rescinded, was adopted.

The recommendations made by the Committee on the Library, in its annual report, were referred to the Board of Government with full powers.

On motion duly made and seconded, it was voted to refer to the Board of Government, with full powers, the question of appointing the special committees of the Society and the selection of members thereof.

On motion of Mr. Sherman, it was voted: That this meeting endorses the work of the Joint Committee on Clubhouse and approves of the scheme as reported to this meeting by the chairman.

President Bryant then delivered the following address:

It is fast becoming the practice for the retiring President to diagnose the real or imaginary evils which beset the Society and prescribe a cure.

In doing this, there is, of course, constant danger of substituting the methods of the ministry for those of medicine, and preaching a sermon. I suspect that what I have to say will partake of both.

A few years ago my predecessor, Mr. Worcester, bewailed the fact that so large a part of the Society work was done by the older members, with a resulting lack of interest and sympathy among the younger men.

Mr. Francis, in his annual address last year, indicated his inability to discover the actual existence of this trouble, and I find myself equally at a loss in locating any symptoms of this sort. I think the younger men have shown great interest in our meetings and excursions, and have contributed much of their time and energy to make both successful. I do think, however, that the attendance at regular meetings is not as large as could be wished, although it is steadily increasing.

The annual reports indicated a jump in the average attendance from 82 to 138 last year. This jump was not so real as it appears, however, since one special meeting with ladies from several other societies accounted for the greater part of the apparent increase.

For the present year, with the same figure of average attendance, and allowing for the joint meetings with the mechanical and electrical sections, and also for one small business meeting, it is apparent that the average attendance of our own members has increased to nearly one hundred.

With a resident membership of about four hundred and fifty, this means that such members attend the meetings on an average of twice a year.

I think this can be bettered, but I doubt if the proper course is to offer technical papers only, or to operate picture shows only, or to provide a free vaudeville only, — or, in fact, to provide any other features which can be found elsewhere in society or in the press.

Let us keep our technical papers and talk and conduct them in as informal a manner as possible, much as our informal meetings are now conducted. Then let us devote perhaps two or possibly four meetings a year to some subject of general interest, like the smoke prevention and electrification subject of this afternoon.

With due respect to precedent, I feel that we engineers as a body do not sufficiently interest ourselves in influencing the conduct of public affairs. We have been too sensitive about having our motives misunderstood, and too fearful that we should criticise the work of some other profession, or of some member of our own.

I do not think it incumbent on us to do the work which is being done by the Chamber of Commerce, for instance, but I do think that careful consideration and forceful advocacy of some one or more of the important questions of the day will give zest to our meetings, which will not only secure increased attendance of our members, but a general participation in the proceedings, which is so much to be desired.

In part this will be publicity work and, like all such, will indirectly react to our benefit.

Still another and important means of increasing the attendance and interest in our meetings is to increase our membership.

As stated at the recent engineering dinner, I am prepared to recommend to the Society that the word "civil" be dropped from our corporate name, and that we become nominally what in a degree we already are in fact, viz., a local body of engineers of all types. It might be wise to so alter our requirements for admission that membership in the various national organizations shall be a direct passport to our ranks.

When accepting office, I promised to follow up the headquarters or club house committee, and to do my best to secure prompt results. I confess, first, that I have not done as much in this line as I intended, and, second, that what little I have done has not been as productive of results as I had hoped.

Many society matters hinge on the satisfactory solution of this problem, and we are all extremely anxious that some definite workable scheme should be promptly set before us. I think that the committee's report will show hopeful signs in that direction.

Before this annual affair is over, you may hear something which, while in jocund vein, undoubtedly represents the thoughts of many of the younger men among our membership. It has been suggested to the Society that a committee should be appointed to collect reliable and comprehensive data regarding the pay of engineers in municipal, corporate and private employment in various parts of the country.

Such information would be of interest and value, not only to employees, but to employers. Of course the work of this committee would involve the expenditure of some money, and I am not ready now to recommend any new expenditures unless some means of curtailing our present current expenses can be devised.

I wish to take this opportunity to express the pleasure as well as honor I have had in serving as your President during the past year. The members, without exception, have coöperated with me most heartily. The new Board of Government has been most efficient, and the regular meetings which are now required have enabled it to dispatch much more business during the past year than ever before. I wish to thank the members of the board for their constant interest and activity.

The members then adjourned to the auditorium of the club house, where members and guests to the number of 155 sat down to the twenty-ninth annual dinner.

After the dinner, President Bryant again called the meeting to order and stated that the subject of the after-dinner talk would be "The Electrification of the Steam Railroads in the Boston Metropolitan District." Prof. George F. Swain opened the subject, speaking from the point of view obtained in the recent investigation and report by the "Big Four" Commission. He was followed by Mr. W. S. Murray, chief electrical engineer of the New York, New Haven & Hartford Railroad, who spoke particularly of the work which that company had done on its New York division and the work now in progress in the electrification at the Hoosac Tunnel on the Boston & Maine Railroad. He exhibited a large number of lantern slides showing details to the work under his charge.

Prof. Dugald C. Jackson also discussed the general subject of the electrification of steam railroads.

On motion duly made and seconded, the thanks of the Society were unanimously voted to Mr. Murray for his courtesy in appearing before the Society and presenting in such an interesting manner the work now in progress towards electrifying the steam railroads.

Before adjourning the meeting, the President expressed his regrets that the President-elect, Mr. Main, was at Panama in connection with the excursion of the American Society of Civil Engineers to examine the Panama Canal. He, however, called on Mr. Frederic H. Fay, Vice-President-elect, who briefly thanked the Society for the honor it had conferred in his election to office and joined in the regrets which all felt at Mr. Main's absence.

In the evening a "smoker" was held in the auditorium of the Boston City Club, at which the attendance was about three hundred. The "smoker" was of the same informal character as in former years, light refreshments being served and excellent music being furnished by an orchestra; the old songs of a year ago were also sung, and in addition, Mr. Josef Yarrach entertained the members for a half hour with card tricks and sleight-of-hand performances.

S. E. Tinkham, *Secretary.*

Annual Report of the Board of Government for the Year 1910–11.

Boston, Mass., March 15, 1911.

To the Members of the Boston Society of Civil Engineers:

In compliance with the requirements of the Constitution, the Board of Government submits its report for the year ending March 15, 1911.

At the last annual meeting the total membership of the Society was 723, of whom 687 were members of the Society, 3 honorary members, 15 associates and 18 were members of the Sanitary Section only.

During the year the Society has lost a total of 28 members: 11 by resignation, 10 by forfeiture for non-payment of dues, and 7 have died.

There has been added to the Society during the year a total of 102 members of all grades; 98 have been elected, 1 transferred from Engineers' Club of St. Louis, 2 reinstated and 1 has been elected to membership in the Sanitary Section. One member has been transferred from the Sanitary Section to the main Society.

The present membership of the Society consists of 2 honorary members,

746 members, 9 juniors, 23 associates and 17 members of the Sanitary Section only; making the total membership 797, a net gain of 74.

The record of the deaths during the year is:

George Leonard Vose, a past president of the Society, died March 30, 1910.
William Jackson died June 30, 1910.
Burton I. Drisko died January 8, 1911.
Joseph R. Carr died January 27, 1911.
Louis E. Hawes died January 29, 1911.
Leonard P. Kinnicutt died February 6, 1911.

Ten regular, three special and one informal meetings of the Society have been held during the year. The average attendance at the regular and special meetings was 138, the same as last year, the largest being 350 and the smallest 22.

The following papers have been read at the meetings:

March 16, 1910. — John R. Freeman, "Los Angeles Aqueduct." (Illustrated.)

March 30, 1910 (special). — William F. Morse, "Practical Questions Concerned in the Collection and Disposal of Municipal Waste." Willis C. Merrill, "Garbage Disposal."

April 20, 1910. — Frederick H. Newell, "Engineering Work of the Reclamation Service." (Illustrated.)

May 18, 1910. — Luis G. Morphy, "East Boston Deep Water Terminals of the B. & A. R. R." (Illustrated.)

May 25, 1910 (special). — Consideration of Amendments to the Constitution and By-Laws.

June 15, 1910. — B. B. Colborne, "Repairing and Resurfacing Streets by the Lutz Surface Heater." (Illustrated.)

September 21, 1910. — Louis K. Rourke, "Work at the Panama Canal."

October 19, 1910. — Prof. Thomas A. Jaggar, Jr., and Prof. Charles M. Spofford, "An Account of the Destruction of Cartago, Costa Rica, by the Earthquake of May 4, 1910." (Illustrated.) Discussion by Frank B. Gilbreth.

November 16, 1910. — Charles R. Gow, "Methods and Cost of Construction of Slow Sand Purification Plant for the new Springfield, Mass., Water Works." (Illustrated.)

December 21, 1910. — Memoir of E. P. Dawley. H. B. Andrews, "A New Theory for Reinforced Concrete Reservoirs." (Illustrated.) Charles H. Dutton, "The Design of Eccentrically Loaded Concrete Members Reinforced on One Face Only."

January 11, 1911 (informal). — Waterproofing of Concrete and Its Behavior in Sea Water."

January 25, 1911. — Memoir of Past President George L. Vose; memoir of William Jackson. Lieut. F. R. Harris, "Dry Docks and Dry-Dock Construction and a Description of the Principles of the Design and the Methods of Construction Employed in Dry Dock No. 4 at the Brooklyn Navy Yard." Discussion by James W. Rollins.

February 15, 1911. — Walter McCulloh, "Water Resources of the State of New York." (Illustrated.)

March 10, 1911 (ladies' night). — Desmond FitzGerald, "Nature Studies in Many Lands." (Illustrated.)

The Sanitary Section of the Society has had five meetings during the year, with an average attendance of 46. It also made an excursion to Hudson on June 1, 1910, in which 25 took part.

The papers read at the meetings of the Section were:

March 2, 1910. — Dr. George A. Soper, "Air Contamination." (Illustrated.)

May 4, 1910. — John H. Gregory, "The Sewage Disposal Plant at Columbus, Ohio." (Illustrated.)

December 7, 1910. — William B. Landreth, "The New York State Barge Canal." (Illustrated.)

December 28, 1910. — Charles Saville, "The Sewerage and Drainage of the Emscher-Genossenschaft, Germany." (Illustrated.)

February 1, 1911. — Prof. Samuel C. Prescott, "The Milk Supply of Boston, its Sources, Quality and Sanitary Importance." (Illustrated.)

The Board of Government has held fifteen meetings during the year, one or more having been held each month, except the month of August.

At the meeting held on June 15, 1910, the Society amended its Constitution and By-Laws. The important changes in the Constitution, relating to membership, are placing a minimum age limit of twenty-four years for the grade of members and establishing the new grade of juniors with a minimum age limit of eighteen years. The number of Directors was increased from two to four, and the three latest past presidents were made members of the Board of Government. The number required to constitute a quorum for the transaction of business was increased from ten to twenty-five.

The important changes in the By-Laws provide for stated meetings of the Board of Government and for the election of new members and of the librarian by the Board, instead of by vote of the Society as formerly. The annual dues of members and associates were slightly increased, those of residents, in both grades, being placed at ten dollars and of non-residents at six dollars; the dues of the new grade of juniors were placed at five dollars for residents and four for non-residents.

In June last the Board established an Employment Bureau, to be a medium for securing positions for members of the Society and for furnishing members and others desiring men capable of filling responsible positions. Two lists are kept on file at the Society rooms, one of positions available and the other of men available, giving in each case such information as has been presented. Brief abstracts from these applications have been printed in the next *Bulletin* issued after their receipt. The Board is very glad to be able to state that this bureau has been the means of securing positions and assistants for a reasonable number of those who have registered.

The pay-station telephone, which was installed in the Society rooms last June, has been a great convenience to those having occasion to use our rooms, and it is hoped that members requiring pay-station service will use this telephone when in the vicinity of the rooms.

Following a suggestion in the address of the President at the last annual meeting, the Society, by vote, instructed the Secretary to prepare a certificate of membership. As he did not feel authorized, under the vote, to call upon the Society to bear the expense of preparing these certificates unless there was reasonable assurance that a sufficient number would be purchased to reimburse the Society, notices were printed in the May and June *Bulletins* requesting members who desired such a certificate to communicate with the Secretary at once. Less than twenty-five responses were received in answer to these notices. As so few of the members seem to care for a certificate of membership, the Board recommends that the vote instructing the Secretary to prepare such a certificate be rescinded.

The second dinner of the engineers of Boston, under the joint management of the American Society of Mechanical Engineers, the Boston Section of the American Institute of Electrical Engineers and this Society, was held this year at Hotel Somerset on January 31, 1911. The attendance was nearly four hundred and was as enjoyable an occasion as that of a year ago.

The matter of awarding a prize each year for the best paper presented to the Society, which was referred to the Board at the last annual meeting, has been considered. Through the generosity of Mr. Desmond FitzGerald, provision has been made for the award of a bronze medal. The design of the medal has been referred to Mr. FitzGerald, and rules for its award were adopted by the Society at the January meeting, the prize to be entitled the "Desmond FitzGerald Medal."

The affairs of the Society appear to be in a prosperous condition, notwithstanding the Treasurer's report of a deficit. This deficit was anticipated last year on account of the difficulty of making any advance in the annual dues which should be in season to materially affect this year's accounts.

An analysis of the Treasurer's comprehensive statement indicates a continuous increase in current receipts during the last four years, those of 1910 being approximately nine hundred dollars greater than those of 1907. It is anticipated that the increased dues will raise these receipts from \$5 600 for the present year to \$6 800 for the coming year.

The expenses for the past four years have increased much more rapidly than the income. If they are no larger this year than for the year past, there will be a surplus of \$300 to apply towards the loan of \$700 from the permanent fund.

It is evident to this Board that rigid economy of current expenditures must be practiced, or additional sources of income must be discovered. The only additional source of income which appears worthy of consideration is the increase in advertisements, and it is doubted whether this can be materially changed to advantage.

In the expenses there is a slow and natural growth in the payments made to the Association for the JOURNAL, but for the items of printing, postage, salaries, reporting meetings, stereopticon and books, the expenditure is increased from over \$1 700 to over \$3 300, or to nearly double the amount of 1907–08. It would appear, therefore, that any reduction must be made in the five items of the Treasurer's report just mentioned.

A further inspection of the Treasurer's figures will show that there has been a considerable shifting in the investment of the permanent fund. An attempt has been made to obtain securities which were entirely safe and conservative, but which would yield a larger income than savings banks, or some of the older securities. The result is that the interest on the permanent fund has been nearly doubled, and is approximately three times that of 1907–08.

The Board has taken no action during the year regarding new headquarters, but it anticipates with pleasure a report from its members on the general committee, or a report from the committee itself.

For the Board of Government,

HENRY F. BRYANT, *President.*

Report of the Secretary for the Year 1910–11.

S. Everett Tinkham, Secretary, in account with the Boston Society of Civil Engineers.

For cash received during the year ending March 15, 1911.

From Entrance Fees:

81 Members	at $10.00 =	$810.00		
8 Associates	at 10.00 =	80.00		
1 Member transferred from San. Sec.	at 5.00 =	5.00		
9 Juniors	at 5.00 =	45.00		
1 Sanitary Section Member	at 5.00 =	5.00		
Total from Entrance Fees				$945.00
From dues for year 1908–09			$8.00	

From dues for year 1910–11 (Members and Associates):

394	at $8.00 =	$3 152.00	
23	at 4.00 =	92.00	
243	at 5.00 =	1 215.00	
6	at 2.50 =	15.00	
666			4 474.00

From dues for year 1910–11 (Sanitary Section):

17 at $5.00 .... 85.00

683 Total number paying dues for 1910–11.

From dues for year 1911–12:

4	at $10.00 =	$40.00	
2	at 6.00 =	12.00	
6			52.00

Total for dues	4 619.00
From sale of Journals	4.50
From advertisements from June 28, 1910	597.50
From rents from July 1, 1910	583.33
Total receipts	$6 749.33

March 11, 1911.

We have examined the above report and found it correct.

(Signed) Frederic H. Fay,
J. P. Snow,
Directors, Boston Society of Civil Engineers.

REPORT OF THE TREASURER FOR THE YEAR 1910 11.

BOSTON, March 15, 1911.

To the Boston Society of Civil Engineers:

The Treasurer submits as his annual report for the year ending March 15, 1911, three tabular statements as follows.

TABLE 1. — PROFIT AND LOSS STATEMENTS.

Income:	1907–8.	1908–9.	1909–10.	1910–11.
Members' Dues	$4 114.00	$4 113.00	$4 332.00	**$4 567.00**
Advertisements	580.00	1 090.00	850.00	**1 004.50**
Library Fines	3.25	4.24	3.50	**4.75**
Sale of JOURNALS	....	....	6.50	**4.50**
Interest on Current Funds	....	....	....	**10.47**
Total Current Receipts	$4 697.25	$5 207.24	$5 192.00	**$5 591.22**
Entrance Fees	$330.00	$600.00	$670.00	**$945.00**
Contributions to Permanent Fund	100.00	100.00	100.00	**200.00**
Interest on Permanent Fund,	415.34	636.72	659.07	**1 231.78**
Receipts account Permanent Fund	$845.34	$1 336.72	$1 429.07	**$2 376.78**
Surplus Account	....	....	....	**1.50**
Deficit, Current Funds	....	....	334.18	**940.26**
	$5 542.59	$6 543.96	$6 955.25	**$8 909.76**

Expense Items:	1907–8.	1908–9.	1909–10.	1910–11.
Association Eng. Societies	$1 272.00	$1 329.50	$1 661.62	**$1 912.62**
Rent (net)	935.00	950.00	950.00	***856.74**
Light	31.03	36.30	48 54	**53.76**
Printing, Postage, etc.	986.62	1 544.16	1 397.48	**1 770.96**
Salaries	550.00	550.00	750.00	**1 007.00**
Reporting Meetings	128.38	100.00	152.50	**282.00**
Stereopticon	90.00	165.00	135.00	**180.00**
Books	41.75	53.35	83.00	**72.10**
Binding	97.25	145.20	73.20	**81.20**
Periodicals	26.50	28.50	36.50	**31.00**
Incidentals and Repairs	229.73	71.19	41.83	**79.45**
Insurance	....	8.88	8.88	**26.38**
Telephone	....	....	....	**59.82**
Sanitary Section	60.00	60.00	60.00	**45.00**
Annual Meeting, etc.	80.60	....	118.88	**43.45**
Depreciation on Furniture	28.00	33.50	8.75	**31.50**
Total Current Expenses,	$4 556.86	$5 075.58	$5 526.18	**$6 532.98**
Transferred to Permanent Fund,	845.34	1 336.72	1 429.07	**2 376.78**
Profit Bal., Current Funds,	140.39	131.66	....	....
	$5 542.59	$6 543.96	$6 955.25	**$8 909.76**

* This should be $935 for a full year, but the smaller amount is to reconcile with statement of accounts receivable and payable, which were not reported last year.

TABLE 2. — COMPARATIVE BALANCE SHEETS.

	March 16, 1910.	March 15, 1911.
Assets:		
Cash	$2 780.05	$260.63
Coöperative Banks	9 022.95	7 447.38
Savings Banks	3 964.15	370.33
Bonds	10 463.00*	19 430.50†
Accounts Receivable	....	270.83‡
Library (estimated value)	7 500.00	7 500.00
Furniture (estimated value)	600.00	598.50
Current Fund Deficit (owed to Permanent Fund),	....	552.75
	$34,330.15	$36,430.92
Liabilities:		
Permanent Fund	$25 842.64	$28 219.42
Current Fund, Balance	387.51	....
Accounts Payable	....	113.00§
Surplus	8 100.00	8 098.50
	$34,330.15	$36 430.92

Increase in net assets for the year........................$1 548.02

TABLE 3. — INVESTMENT OF PERMANENT FUND, MARCH 15, 1911.

Bonds:		Value (1910).
4	$1 000 Boston El. Ry. $4\frac{1}{2}$ per cent bonds, due 1937, principal registered, at $105\frac{1}{2}$, =	$4 220.00
3	$1 000 Am. Tel. & Tel. Co. 4 per cent col. tr. bonds, due 1929, principal registered, at $91\frac{1}{4}$ =	2 737.50
1	$600 Republican Valley R. R. 6 per cent bond, due 1919, at 103 =	618.00
3	$1 000 C. B. & Q. R. R. joint 4 per cent registered bonds, due 1921, at $96\frac{1}{4}$ =	2 887.50
2	$1 000 Union El. Lt. & Pr. Co. 5 per cent bonds, due 1932, principal registered, at $102\frac{1}{2}$ =	2 050.00
2	$1 000 Blackstone Valley Gas & Elec. Co. 5 per cent bonds, due 1939, principal registered, at $99\frac{3}{4}$ =	1 995.00
2	$1 000 Harwood Elec. Co. 5 per cent bonds, due 1939, principal registered, at 98 =	1 960.00
2	$1 000 Dayton Gas Co. 5 per cent bonds, due 1930, principal registered, at 100 =	2 000.00
1	$1 000 Milford & Uxbridge St. Ry. Co. 5 per cent bonds, due 1918, principal registered, at $96\frac{1}{4}$ =	962.50
		$19 430.50

* Bonds taken at market value, which is $169.50 less than par value.

† Without allowance for changes in market value during the year, which have been slight.

‡ Rent from subtenants, to March 1, 1911.

§ Dues paid in advance, $52; telephone rental, $61.

Savings Banks:

Boston Five Cent Savings Bank (including interest to October, 1910)	$127.41	
Franklin Savings Bank (including interest to February, 1911)	242.92	
		$370.33

Coöperative Banks:

25 shares Merchants Co-operative Bank (including interest to March)		$3 403.85
25 shares Workingmen's Co-operative Bank (including interest to March)		1 561.08
25 shares Volunteer Co-operative Bank (including interest to January)		2 482.45
		$7 447.38
Cash in Old Colony Trust Company		260.63
Due from Current Funds, account deficit	$552.75	
Due from Current Funds, account difference between accounts receivable and accounts payable	157.83	
		710.58
Total Permanent Fund		$28 219.42

COMMENTS UPON TABLES.

Table 1 contains profit and loss statements for the three preceding years, as well as for the year 1910–11. This includes all transactions, those relating to the Permanent Fund as well as current fund accounts, but the items are separated so that each can be taken by itself. It is seen that the current income amounted to $5 591.22, and current expenses $6 532.98, showing a deficit of $941.76. There has been added to the Permanent Fund $2 376.78, of which $1 231.78 was for interest. (The increase in the Permanent Fund last year was $1 429.07.)

In examining the balance sheets at the beginning and end of the year, it should be remembered that no account is taken of any interest accrued since the last regular interest periods of the several investments; also of the fact that some of the advertisers have paid in advance for advertising not yet received; rent due to and from the Society has been computed to March 1; and the cost of the March, 1911, *Bulletin* is not included. These conditions are the same every year, although the amount corresponding will vary somewhat.

A portion of the Permanent Fund has been loaned to the Society for its current needs, by authority of the Board of Government, in order that no bills should remain unpaid at the end of the year. The amount of the loan is $710.58, although only $552.75 of this represents an actual shortage of resources; the remaining $157.83 is required because certain rents due the Society have not yet been collected.

Respectfully submitted,

CHARLES W. SHERMAN, *Treasurer*.

BOSTON, March 15, 1911.

We hereby certify that we have examined the Treasurer's accounts for the year 1910–11; that all receipts are properly accounted for, and that there are proper vouchers for all payments. The accounts are correctly cast, and the net results, namely, a deficit of $710.58 in the current fund, and a cash balance of $260.63 in the Permanent Fund, are correct.

One of us has also examined the securities and investments belonging to the Permanent Fund, and finds them to be as stated in the table accompanying the Treasurer's report, — showing a present book value of $28 219.42, which is $169.50 less than the par value.

F. H. FAY,
J. P. SNOW,
Directors.

REPORT OF THE LIBRARY COMMITTEE.

The fortieth annual report of the library since it was organized, and the report for the year 1910–11, is herewith submitted.

The number of books added to the library the past year has been 392, of which 163 were bound in cloth and 229 in paper. Many of the bound volumes consist of magazines and society publications or of municipal reports, received in paper and bound in convenient form. The library now contains 6 742 volumes in cloth.

Our honored fellow-member and liberal giver, Mr. Clemens Herschel, has been especially generous the past year, perhaps most notably in the gift of the entire works of Herbert Spencer, fresh from the publisher. It may be explained here that Mr. Herschel donates mainly two classes of books, those on engineering subjects, and books on any subject written by men who at some time in their career followed the engineering profession. One new section has lately been added to the Herschel library, but more room should speedily be furnished for it, as all these sections are overflowing. A number of the Herschel books have been bound in cloth in conformity with an agreement with Mr. Herschel.

During the year, 228 books have been loaned to members. Fines on books have been collected amounting to $4.75.

The plan-case bought two years ago for the preservation of the United States government topographical sheets is now packed with these plans, so that they are almost inaccessible. These plans are rapidly increasing in number, and a second twelve-drawer plan case should be bought at once, as previously recommended.

Five book reviews have been written by members, for which the thanks of the committee are hereby tendered.

The one crying need of the library is for more room, but this cry has been chronic so long that it is too well understood to require comment. The committee would suggest that a storage room be procured, not necessarily near the library, where books not in use can be stored until the Society secures larger quarters.

Out of the sum of $75 appropriated for current engineering books, twenty books have been bought at a cost of $64.35, and every current volume asked for by any member has been bought.

The following four specific recommendations are made:

(1) That $75 be appropriated for the purchase of current engineering books the coming year.

(2) That $30 be appropriated for the purchase of a second plan-case.

(3) That a room be hired for storage.

(4) That a number of sections be bought for the proper housing of the Herschel library.

FREDERIC I. WINSLOW,
H. T. STIFF,
J. M. SINER,
G. V. WHITE,
EDWIN R. OLIN,
Committee.

REPORT OF THE COMMITTEE ON EXCURSIONS.

To the Members of the Boston Society of Civil Engineers:

During the past year ten excursions have been made by the Society, as follows:

	Attendance.
April 20, 1910, to the American Sugar Refinery Company, South Boston,	7
June 15, 1910, to the Grade Crossing Elimination at Worcester, Mass...	40
August 24, 1910, to the Cape Cod Canal (21 automobiles)............	94
September 12, 1910, to the Harvard Aviation Meet, Squantum, Mass...	160
September 21, 1910, to the Massachusetts Cotton Mills, Lowell, and Arch Bridge at Nashua..	24
October 19, 1910, to observe tests of concrete beams at the Massachusetts Institute of Technology laboratories.........................	30
November 16, 1910, to Filter Beds at North Attleboro, Mass............	30
December 21, 1910, to the Beacon Hill Tunnel.........................	100
January 25, 1911, to the Cambridge Subway..........................	210
February 15, 1911, to the New United States Custom House, Boston, Mass.,	75

Total attendance, 770; average attendance, 77.

The committee has continued to collect data as to "new engineering work," either in progress or contemplated, for publication in the *Monthly Bulletin* of the Society, and has contributed thirty-six pages to the nine *Bulletins,* — four pages per issue.

Messrs. T. W. Norcross and G. E. Howe resigned from the committee and Messrs. L. E. Moore and F. L. Murray were appointed to take their places.

There is a balance in the hands of the committee of $53.14.

Respectfully submitted,

FRANK H. CARTER, *Chairman.*
H. K. HIGGINS.
L. E. MOORE.
F. L. MURRAY.
RICHARD K. HALE, *Secretary.*

REPORT OF THE EXECUTIVE COMMITTEE OF THE SANITARY SECTION.

BOSTON, MASS., March 1, 1911.

At the annual meeting of the Sanitary Section, held March 2, 1910, the following committees were continued: On Rainfall and Run-Off; on Collection and Tabulation of Sewerage Statistics; and on Uniform Specifications for Sewer Pipe.

The following papers (all illustrated with lantern slides) have been read and discussed at regular and special meetings:

March 2, 1910. Dr. George A. Soper, "Air Contamination."
May 4, 1910. John H. Gregory, "The Sewage Disposal Plant at Columbus, Ohio."
December 7, 1910. Wm. B. Landreth, "The New York State Barge Canal."
December 28, 1910. Charles Saville, "The Sewerage and Drainage of the Emscher-Genossenschaft, Germany."
February 1, 1911. Prof. Samuel C. Prescott, "The Milk Supply of Boston, Its Sources, Quality and Sanitary Importance."

On June 1 the Section made an excursion to Hudson, Mass., visiting the wool waste recovery plant of the Hudson Worsted Company and the sand filter beds of the town of Hudson. The party, numbering twenty-five, then took the train to Wayside Inn where dinner was served and a pleasant afternoon spent.

The attendance at meetings has been as follows:

Annual meeting	43
May meeting	45
December 7th meeting	40
December 28th meeting	60
February meeting	40

Exclusive of the June excursion, the average attendance at meetings has been 46; the average attendance for previous year was 49.

The additions to the membership of the Section are as follows: *By election*, 1 member. *By enrollment from the Society*, 4 members.

Number of members who are also members of main society	142
Members of Sanitary Section only	18
Total membership of Section	160

During the past year the Constitution and By-Laws of the main society have been so amended that no further enrollment can be made for membership in the Sanitary Section alone, and eventually all members of the Sanitary Section will thus be members of the main society. It is believed that no serious detriment will be occasioned thereby to the growth of the Section, as, in the case of persons engaged actively in sanitary work who may not be eligible for or care to assume full membership in the main society, they may, by becoming associate members of the main society, be eligible for membership in the Sanitary Section.

Interest in the work of the Section seems unabated, and it is evident that its meetings enable the presentation and discussion of subjects of importance to sanitary engineers, for which sufficient time is not available in the program of the main society.

For the Executive Committee,

H. K. Barrows, *Clerk.*

Report of Committee on Rainfall and Run-Off.

The Committee on Rainfall and Run-Off of sewered areas begs leave to submit the following report:

Your committee hoped that during the year past it would be able to interest more engineers in the work in which it was engaged, and that it would

be able to report more gaging stations in operation at this time. It has found it practically impossible, however, to do this.

All it can report is, that records are still being taken in three cities and that in two of these cities the data have been reduced to a form suitable for publication. It also has other data that it hopes soon to put in shape for publication

The committee realizes that it requires a large amount of perseverance and much careful oversight to obtain records of any value and that observation must be continued over a considerable period of time.

A single experience will illustrate this. In the year 1910, in the city of Pawtucket, there were one hundred and nine storms recorded on the rain gage, but only sixteen of these storms gave run-off data worth tabulating. Observations taken in this city since April, 1905, have given only sixty records that were complete and of any interest.

It is to be noted, however, that the last three years have been years of very low rainfall, and therefore deficient in record-producing storms.

Several gaging stations have been established in Fall River, Mass., but no records have yet been obtained.

The committee has been in correspondence with a committee of the Municipal Engineers of New York City, engaged in a similar undertaking, and has been promised a copy of the data collected by that committee during the year 1910.

Your committee would, therefore, suggest that it be given authority to publish in the JOURNAL the data collected, just as soon as it can be put into a form for publication.

Respectfully submitted,

GEO. A. CARPENTER, *Chairman.*

REPORT OF COMMITTEE ON MANUFACTURE OF SEWER PIPE.

BOSTON, MASS., February 27, 1911.

TO THE MEMBERS OF THE SANITARY SECTION, BOSTON SOCIETY OF CIVIL ENGINEERS:

Gentlemen, — Your Committee on Manufacture of Sewer Pipe, which was continued by vote of the Section at the last annual meeting, in order to coöperate, if occasion should afford, with the committee appointed by the American Society for Testing Materials, to investigate the subject of the manufacture of sewer pipe and to consider the feasibility of the adoption of standard specifications therefor, regrets to report but little substantial progress. Mr. F. A. Barbour, a member of the committee, who is also a member of the committee of the American Society for Testing Materials, reports that an elaborate set of tests has been outlined, the carrying on of which will necessitate a considerable lapse of time, and the appropriation of more or less money. It appeared to your committee, therefore, that it would be distinctly unfortunate for the Sanitary Section to suggest standard specifications at this time, which might require substantial modification hereafter, in the light of the results obtained from the proposed experiments, particularly as the specifications would not be likely to accomplish anything in the direction of unifying practice or of modifying the present incongruities, relative to the thickness of sewer pipe of the different dimensions.

In the light of the fact that delay is likely to be substantial, your committee asks to be discharged, unless it shall be thought desirable to continue it for service, in case of possible coöperation between this Section and the American Society for Testing Materials.

Respectfully submitted,

LEONARD METCALF, *Chairman.*
F. A. BARBOUR.
E. S. DORR.
CHARLES R. FELTON.
LOUIS D. THORPE.

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., MARCH 13, 1911. The third regular meeting of the year was called to order in Society's quarters in Old State Capitol Building at 8 o'clock P.M. by President L. P. Wolff. There were present twenty members and five visitors.

The minutes of the previous meeting were read and approved.

A letter was received and ordered read from Mr. W. W. Curtis, a trustee of the Western Society, setting forth the advantages to be gained by this Society affiliating with the Western Society. Said letter responded to a communication which the Society ordered directed to Mr. Curtis and in which it expressed its desire to be further advised relative to the proposition of so affiliating with the Western Society, and submitted to this Society at its February 13 meeting by Mr. Curtis. On motion carried, the matter and all papers were placed in the hands of a committee consisting of J. H. Armstrong (chairman), Adolph F. Meyer and Harry C. Palmer, with instructions to look into the matter thoroughly and report back their findings with recommendations to the Society at its next meeting, which will be held on the evening of April 10.

The name of Watson Townsend was dropped from the membership rolls of the Society for non-payment of dues.

The applications of James E. Carroll and John Fennimore Druar for full membership in the Society were introduced and ordered read; upon motion carried the Secretary was directed to cast the ballot of the Society for the election of the applicants as petitioned. They were declared elected.

The committee having in hand the resolution introduced at our previous meeting which related to a measure now under consideration in the state legislature, which measure contemplated enlarging the duties of the engineering division of the Minnesota State Board of Health, reported progress.

Paper entitled "The Gas Engineer and the Gas Industry," by Russell Feurtado, was read, but owing to lack of time discussion on same was postponed to some future time.

Paper entitled "Water Resources Investigation in Minnesota," by Robert Follansbee, was read and discussed. Both contributors received the thanks of the Society, and the Secretary was directed to have the papers published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

There being no further business, meeting adjourned.

D. F. JÜRGENSEN, *Secretary.*

Montana Society of Engineers.

BUTTE, MONTANA, FEBRUARY 11, 1911. — The Society's meeting for February met at regular place and time, with President Whyte in the chair. The minutes of the last annual meeting were approved as read. The Secretary presented the applications of Messrs. Frank C. Noble and Ulysses A. Garrard for membership in the Society; the same were approved and the ballot ordered. Messrs. McIntire, Curtis, Kyd, Fearnall, Hervin, Stockett and Williamson were elected to membership by a unanimous vote. The President appointed the Committee on State Roads for the coming year as follows: Clinton H. Moore, Charles W. Goodale, Archer E. Wheeler. The Secretary was instructed to invite Mr. C. W. Goodale to prepare his remarks at the annual meeting on the Panama Canal for publication in the JOURNAL of the Society. The Society then adjourned.

CLINTON H. MOORE, *Secretary.*

Technical Society of the Pacific Coast.

THE annual meeting of the Society was held on Friday, February 24, at the Palace Hotel, where a number of members and their ladies gathered to meet at a banquet table.

President George W. Dickie presided. After the dinner the Secretary read the minutes of the last regular meeting, and the President appointed as tellers to open the ballots for the newly elected officers, Messrs. Uhlig and Lietz.

The report of the Treasurer was then read as follows:

REPORT OF THE TREASURER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST FOR THE YEAR 1910.

Balance in bank, January 10, 1910	$860.58	
Money on hand, January 10, 1910	9.00	
Received during the year 1910	612.33	
		$1 481.91
Expended during the year 1910	$589.57	
Money on hand, January 10, 1911	8.00	
Balance in bank, January 1, 1911	884.34	
		$1 481 91

Receipts.

Cash in bank	$860.58	
Cash on hand	9.00	
Dues collected	594.00	
Three admission fees	15.00	
Sundries, exchange	3.33	
		$1 481.91

Expenditures.

Sundries, stamps, postage and mailing	$30.35	
Salary of Secretary, twelve months	180.00	
Four assessments to Association of Engineering Societies,	270.62	
Office work and collection	19.35	
Printing	40.25	
Mechanics Institute life members' dues	9.00	
Funeral expenditure	25 00	
Lantern slides	15.00	
	$589.57	
Balance in bank, January 10, 1911	884.34	
Cash on hand	8.00	
		$1 481.91

Respectfully submitted,

E. T. SCHILD, *Treasurer.*

JANUARY 11, 1911.

The tellers thereupon announced that they had opened the ballots, and that the following members were regularly elected officers for the year 1911.

President — George W. Dickie.

Vice-President — Loren E. Hunt.

Secretary — Otto von Geldern.

Treasurer — E. T. Schild.

Directors — Edward F. Haas, Hermann Kower, Bruce Lloyd, Henry A. Schulze and G. Alexander Wright.

The Secretary thereupon read, from the records of the Society, a short history and synopsis of the work of the Technical Society, as follows:

The Technical Society of the Pacific Coast was at one time the most important organization of the kind on the western side of our immense country; it was peculiarly situated in its environment, and it is well to make a few observational remarks on this condition before proceeding further.

In that section of the United States known as the Pacific Coast, twelve hundred miles long, averaging from two hundred to four hundred miles wide, and embracing, in whole or in part, six states and territories, there was and there is, in proportion to population, a much greater amount of what may be called "technical activity" than in the eastern states. It is difficult to define this activity, because even agriculture in most of its phases is of an engineering character, and when allied with irrigation it becomes an intricate technical problem, which the Germans term *Kultur* engineering

Not only is the amount of engineering in the full meaning of its technological sense more extensive in proportion to population than in the eastern portion of the republic, but the pursuits are infinitely more diversified In this respect there is no parallel that may be referred to. The narrow market, or rather its diffused condition, prevents the organization and centralization of industry. There is a cosmopolitan population brought here from all parts of the world, — people who have brought with them their skill and acquaintances with the useful arts and professions. The search for a mild temperature and the climatic conditions that exist on the middle coast have caused an influx of all classes much faster than assimilation was possible. These people cannot be idle. hence there is scarcely a department of human industry that is not in some way represented among the multifarious pursuits of the Pacific Coast, and this condition will increase all the more as the importance of our state grows and its interests expand.

Among these interests is mining, devoted to nearly all kinds of minerals, involving numerous reduction processes, with the plants for carrying them on, which require mechanical apparatus the most complicated and extensive that has ever been produced in any country for obtaining, raising and conveying minerals.

Hydraulic operations were carried on to an extent and of a character that have made the Pacific Coast a center of research. This field has pro-

duced many marked advances in the conservation, conveyance, raising, and distribution of water; also in the application of high heads to motive power, demanding novel mechanical devices, operating under new methods that are just now the subject of interesting research.

In this connection, too, is that vast field of special engineering which has taken a name and place as a separate and extensive branch. We allude again to irrigation, or the application of water to arid soil, and to various growths thereby ennobled and fructified, involving not only the physical conditions of collecting, conveying and distributing the life-giving element, but also the study of its effects upon the soil and the chemical problems that require the constant consideration of the irrigation engineer.

In the same connection, again, are the variation of precipitation and the physical phenomena that attend a difference therein, which is as 3 to 60 in a distance of one thousand miles of the coast line, causing characteristics of streams, growths and climate that afford an endless opportunity for technical research in their application to practical life.

In the way of natural phenomena, this country abounds with strange and fascinating curiosities, presenting chemical and geological problems that invite thought and careful study.

The existence of subterranean water in the gravel strata of sedimentary lands, and the artesian basins of wonderful extent, also furnish to the engineer and geologist problems of not only scientific but also of practical interest.

The approaches from the sea and the accessibility of the coast to shipping, the safety and capacity of our coast harbors, and the navigability of the rivers for the purpose of water traffic, are special fields in which the Pacific Coast engineer will find ample opportunity to exhibit his skill and knowledge. The time is near when the question of coast harbors will be a very material one to the interests of our states, and with it the improvement of the navigable rivers will go hand in hand. Opportunities are offered for original research in this field which cannot be exceeded anywhere in the world The successful drainage of the great Sacramento Valley alone suggests a vast problem, which has become a most vital and important one to a wealthy and prosperous population of farmers and horticulturists. As yet this problem has not been solved. Intimately connected with it is the successful restraint of mining débris, a question which is also awaiting its practical solution, and to which many intelligent and industrious communities scattered throughout the Sierras are looking with an unabated interest.

The immense treasures that lie buried under the mountains are sure to be lifted sooner or later, and that without harming the farming interests of the beautiful and productive valleys below. A way is certain to be found to benefit both valley and mountain interests.

While the thought has turned to gold dredging, which had been uneconomic until proper machinery was invented, so will the resourceful mind of the Californian turn again to those storehouses of gold, as soon as the river dredging methods have ceased to be profitable.

There is work to do, and enough of it, — work that will bring manifold reward to the engineer who is called upon to battle with this one great problem alone.

The improvement of harbors and rivers and the lighthouse construction of the coast are carried on by the government, executed mainly by the corps of engineers. Prominent in this particular branch of the technical profession was the late Col. George H. Mendell, of the United States Engineer Corps, the first president of the Technical Society, a gentleman who was for many years closely identified with all the noteworthy engineering problems of our coast. Allied to the improvement of the harbors is their proper defense, a subject that has had the most careful consideration and attention of the federal authorities within recent years.

The mechanic arts of our coast were at one time extensive and diversified. Unfortunately these industries have suffered, more particularly in the great city of San Francisco, and the rehabilitation of their activity should be the very first aim of the technical man. Industries give employment, employment circulates money, and the city of industries becomes one of self-support, depending upon herself and her manufactories above everything else. "Restore the industries" should be the watchword of the technologist. The entire future depends upon it.

What has been done in the past is as unique as it is marvelous, and it only gives us cause to regret that the progress of our industrial activity was ever checked.

But we, who believe in our future, know that a city capable of resurrecting herself from her very ashes within the short period of five years will overcome all other obstacles to her growth and to her industrial prestige in time.

The building of the great battleships for the United States Navy, and the many merchant steamers of a high class, indicate what has existed in the line of marine engineering and shipbuilding.

The ponderous plant of the Comstock mines, of which a single pumping engine cost a quarter of a million dollars, has shown the technical world how capable and how original our pioneer engineers were.

The extensive manufacture of high explosives, and the numerous other industrial articles manufactured on a larger or smaller scale, point clearly to the fact that we have a claim for diversity.

In the future and rapid development of our state, electrical energy will do its share. And was there ever a country so favorably situated as California to obtain this energy? With its great mountain ranges, its abundance of water thereon, and its facilities for storing it and dropping it from a higher to a lower elevation, there is no country like it.

This means light and power forever, and these two words may be taken in another sense or meaning, for the people who have light will dispel darkness, and the possession of great power must make them powerful.

We need such a race on the Pacific Coast to take up a still greater development, — that of the Pacific Ocean. This ocean will become the theater of the world's history before this century ends. The scenes have been shifted from the Mediterranean to the Atlantic, and in due time they will shift to the world's greatest ocean at our door; the setting of these scenes thereafter belongs to us by right of intelligence and by right of inheritance, and to maintain this leading position, and to defend it, we need, if it may be so expressed, all the light and all the power with which the great God has endowed us.

Turning now to the learned societies and professions, we find on the Pacific Coast a full measure, and a record that needs no explanation. In geology, astronomy, geography, history, electrical technology, chemistry and pure science there are here to be found contributions that naturally arise from a cosmopolitan population. From these redundant sources is drawn the membership of the Technical Society; and, coming now to the particular facts of its existence, we can do no better than quote from the old records:

The Technical Society of the Pacific Coast has not been evolved from a small beginning and a few members, as is common in such cases; but it has been obliged, nevertheless, to follow the inexorable law of evolution, of which the main element is time. The Society was founded in 1884, and the roll signed at the time of its organization contained the names of 61 civil engineers, 30 mechanical engineers, 12 mining engineers, 11 architects, 6 chemists and 2 patent attorneys; in all, 126 members. This was an extraordinary beginning, not only in respect to the number of charter members, but also in the character and qualifications of those enrolled. It included most of the eminent engineers in San Francisco, and, as an assemblage of people engaged in technical pursuits, it could not, perhaps, have been excelled among an equal population in any other part of the United States.

As a result of this, the first papers presented and read before the Society were remarkable. They speak for themselves, and we may digress here to say that the value of these papers was reciprocal, and their influence much wider than commonly supposed. A look through them recently discloses the fact that, in most cases, the papers presented have aided and greatly promoted the interests of those who contributed them. The members who prepared these essays have become distinguished in the branches to which their papers related. Perhaps they were so before, but there is a fair inference that the time and pains invested in the work have been well returned.

The Technical Society's history for several years was nearly what inference would assign. The ablest members presented able papers on the subjects with which they were most familiar, and continued to do so for a number of years, during which the Society flourished. Then came a season of apathy. Why? Because there was no effort to connect the Society's work

with the active industries and interests of the community. It was purely a scientific association, such as this utilitarian country is not yet ready for, and will not be for a long time to come. We may cultivate and promote scientific research in this country, and we do so to an extent within our limits, but we cannot afford to do this in the abstract, as it is done in Europe. There the commonwealth is the great fact of a country; here it is the person and his business; and everything, to succeed, must be connected in some way with the active affairs of life, and it must involve a factor of dollars and cents.

And what is there that should appeal to us more than the application of scientific principles and scientific research to practical life? Does not the great universe illustrate to us that its all-pervading intellect manifests itself in the practical works of its creation?

In respect to the field in which the energy and influence of the Society are to operate, or to which its efforts are particularly directed, it will not be too much to claim that it is peculiar or even anomalous. On this coast the extent of engineering and technical work in proportion to the population is not only vastly more than in other communities of like extent, but is varied in a degree that has no parallel in any country. These peculiar circumstances arise not only from a diversity that embraces nearly all the industries of our time, but to peculiarities of methods and requirements that arise out of climatic and other physical conditions peculiar to the Pacific Coast. This peculiarity must be understood in order to understand our people.

In conclusion, it will be proper to revert to the fountainhead, so to speak, — to the school and the teachers, on whom depends the membership of this Society when our day is past, the faculties of our technical colleges. They have to a great extent aided and promoted this Society in the past by contributions, counsel and membership. To them we stand much indebted.

In the wide and bewildering field which has barely been hinted at, our Society must dig and delve after new truths, each member contributing his part; and here let me say that his part may be a very useful one if he does no more than come to hear and aid us with his presence. The courtesy that has marked the proceedings of the Technical Society is such that no one need fear a respectful hearing of what he may have to present or to say, and it is hoped that in the future there will be a wider participation in the proceedings by all.

We all have great hopes for the future, and there is every reason to expect that the Technical Society will remain a factor in California whose influence will be felt in all the engineering enterprises of this country, and that by its advice the commercial interests of the Pacific Coast will, in a measure, be guided and properly advanced. The necessity for such an active organization is obvious, and as the Society prospers and gains in numbers, its standing in the community and its opinions will grow in importance and in popular value. Such a future existence of usefulness was the ideal held in view by the founders of the organization, and in that direction every effort has been made by those who have had the management of its affairs in hand.

One of the most active of its organizers was the first vice-president of the Society, the late George J. Specht, who gave a great deal of his time and attention, in a most unselfish way, to further the prosperity of the engineering organization. It was a most unfortunate occurrence for this Society when he died in 1888, at a time when the first enthusiasm of the members had somewhat cooled, and when it required a self-sacrificing energy to continue and carry on the work against the odds of a general apathy.

This seems a fit opportunity to refer to our lamented fellow-member. He was born in Holstein, Germany, in 1851, and graduated at the gymnasium of that place. After serving with the German army and participating in the Franco-Prussian War, he began his studies in civil engineering, graduating at the polytechnic school of Graz in 1874. His professional practice was had on the Austrian railways; he was connected with the Crown Prince Rudolph Railway in 1875, and with the Gotthard Railway, in Switzerland, until February, 1877, when he came to California. On the Pacific Coast he entered private practice, locating at San Francisco, where he soon became prominently connected with a number of engineering works. While assistant in charge of the San Diego drainage system in Southern California, during a spell of exceedingly warm weather, he was afflicted with the malady which caused his death.

His death was certainly an irreparable loss to the association. But his memory is still cherished and held in reverence by the older members who had the good fortune to know him. The work of the Technical Society and its mission were taken up as an inheritance from this man, who had labored so faithfully in shaping a course to be pursued, but who had to leave his task undone and submit it to the hands of others.

Prominent among the membership were some of the old charter members of the Society, men who were always ready to work in the interest of this once prominent organization. Mention should be made of the late Col. George H. Mendell; the late George F. Allardt; the late Mr. Curtis, of the Southern Pacific Railway; the late Mr. George W. Percy, one of our prominent architects; the late Mr. P. J. Flynn, at one time the best-known irrigation engineer in California; and the late James Spiers, one of the old representatives of the iron industry in San Francisco.

Of the past-presidents and officers who devoted much of their time to this Society we may mention: Mr. C. E. Grunsky, Mr. D. C. Henny, Mr. Marsden Manson, Mr. E. J. Molera, Mr. Franklin Riffle, and the first secretary, Mr. Charles G. Yale, Mr. H. C. Behr, and Mr. George W. Dickie, the present head of this assemblage; and many others who have served it faithfully in various offices that the Society bestowed upon them.

One of the most energetic of members, whose activity and earnestness of purpose we all remember, is John Richards, a mechanical engineer of wide reputation and unusual skill, who was its president about fifteen years ago for a number of years. Many professional papers testify not only to his ability as a writer and to his mechanical knowledge, but to his ever-ready hand to promote the interests of all. One of the most interesting papers and perhaps the most valuable that the Society possesses is his "Abrasive Processes in the Mechanic Arts," published in the transactions of 1891, which, in its conciseness and clearness of language and the interesting manner of imparting valuable information of which so little is generally known may be justly called classic. This paper was widely circulated and read with unusual interest.

Mr. Richards was a consulting engineer in private practice, who now lives the retired life of an engineer whose duty was well performed. Sausalito is his present home.

I need not refer to Mr. Dickie and the obligations under which the Society is to him. He is here in person and we trust that he may be with us for many years to come.

He will have something to say about the coming epoch, the awakening of our industry with the advent of the great Canal, which the American technical man is making a reality.

A new era will open with the union of the two oceans. It may be one of peace; let us hope it. It may be one of war; let us be prepared for it. A universal peace may be "a consummation devoutly to be wished," but the past history does not seem to point to it as an ever possible reality. It seems as though there never had been the realization of a great human accomplishment without dire struggle. The progress of our mother earth and her present condition have been brought about and made possible by a constant struggle between antagonistic cosmical forces that have been active from the very beginning of her nebulous birth. With the end of the struggle, with the end of the fight, there will be death. Inheriting this desire to overcome and to struggle, the human family will probably continue to fight for supremacy and for advantages until it exists no more. Let our fight be an honest one, and all is well.

But, to return to our Society, — the world may yet realize that the engineer was not only the man of the past, but that he is certain to be the man of the future, for the problems he deals with are too closely related to the human race to be over-looked or neglected.

In the person of our worthy President we have a representative of the engineering profession, the works of which are imperishable realities.

Mr. Dickie thereupon arose and addressed the assemblage, referring also to the past history and to the future of the Society. He dwelt at length on the adven of the great canal, and made the principal subject of his re-

marks the coming Panama Exposition, which is to be held in San Francisco in 1915.

The burden of this subject was taken up by other speakers, who pointed out certain conditions, and to the necessity of the technical man to do some of the struggling for the recognition which is due him.

It was Mr. Henry A. Schulze, who spoke from the standpoint of the architect, and who pointed out the necessity of some concerted action.

Other speakers followed him. Mr. C. E. Grunsky, Mr. Marsden Manson, Mr. G. Alexander Wright and Mr. Medina all spoke on the necessities of the coming exposition, and the relation of our technical man thereto.

Mr. and Mrs. Charles E. Ker entertained the assemblage with song and music, and other guests did their share to make the evening a pleasant one.

Mr. Dickie informed the guests that the Technical Society has joined an association of scientific organizations, which was perfected at the Faculty Club of the University of California some months ago.

The societies now components of the Pacific Association of Scientific Societies are the following:

The Cordilleran Section of the Geological Society of America, the Seismological Society of America, the Pacific Coast Branch of the American Historical Association, the Pacific Slope Association of Official Economic Entomologists, the Pacific Coast Palæontological Society, the Philological Association of the Pacific Coast, the Cooper Ornithological Club, the California Academy of Sciences, and the Technical Society of the Pacific Coast.

A meeting will be held by the end of March, when these societies will gather at the University of California, and in final session at San Francisco, on which occasion ex-President Roosevelt and the presidents of our two great universities will address the joint meeting.

After singing " Auld Lang Syne " the annual meeting of the Technical Society adjourned.

Otto von Geldern, *Secretary.*

Meeting of the Board of Directors, held March 11, 1911, at the residence of the Secretary, 1926 Broadway, San Francisco.

The meeting was called to order by President George W. Dickie.

Present: Directors Hunt, Wright, Lloyd, Schulze, Schild and the Secretary.

The President related in detail the result of the interview which the engineering committee, consisting of the presidents of the four local engineering associations, appointed at an informal gathering of engineers on March 4, 1911, had had with the members of the Executive Committee of the Pacific Panama Exposition, and after very careful explanation of the present status of existing relations, it was ordered that President Dickie's action in this connection be ratified and that he be requested to continue the program undertaken by the engineers in the matter of obtaining a certain recognition of our local engineers in the solution of technical problems that will arise in the planning of the great work of the exposition.

The President then brought up the matter of the coming meeting of the Pacific Association of Scientific Societies, of which the Technical Society is a member, and which is to be held in Berkeley on Thursday, the 30th, Friday, the 31st of March, and Saturday, the 1st of April.

He stated that the following societies were now components of the Association: California Academy of Sciences, Pacific Coast Branch of the American Historical Association, The Cordilleran Section of the Geological Society of America, The Seismological Society of America, Pacific Coast Palæontological Society, The Pacific Slope Association of Economic Entomologists, The Cooper Ornithological Club, The Philological Association of the Pacific Coast, Japan Society of America, The Technical Society of the Pacific Coast.

He informed the directors that an effort is being made to hold separate meetings of the different societies, and that a joint session of all of them will be held, at some suitable place to be chosen, where the gathering will be addressed by representative speakers of the component organizations.

It was agreed that Mr. Dickie should address the joint session on the subject of "Recent Engineering Activities and Important Problems to be Solved by the Engineer," as suggested by Prof. George D. Louderback, the secretary of the Association.

The President also designated Mr. C. E. Grunsky to speak on that occasion, on the subject which was suggested, namely, "Work on the Colorado River."

It was agreed that a regular meeting of the Technical Society be held at Berkeley, on Friday evening, March 31, and that the Secretary make the necessary arrangements to obtain suitable papers, by requesting a number of the known writers of the Society to prepare some technical subject for the occasion.

It was likewise agreed that the Society take part in the joint session to be held April 1.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Association

of

Engineering Societies.

Vol. XLVI. **APRIL, 1911.** No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, March 15, 1911.—The 701st meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, on Wednesday evening, March 15, 1911, at 8.15, President Von Maur presiding. There were present twenty-one members and fourteen visitors.

Mr. M. C. Byers was elected to membership in the Club.

Applications for membership were read from R. L. Williams, C. W. Martin and L. R. Bowen.

Mr. H. A. Wheeler presented the paper of the evening, on "The Latest Developments in the Illinois Oil Fields."

Mr. Wheeler gave a brief history of the development of the Illinois field, explained its geology and presented statistics on the number of wells drilled, the wells in operation, and the output in the various districts in the United States; which showed that the Illinois field is rapidly becoming one of the most important in the country. The paper was illustrated by lantern slides showing views of the machinery and derricks and also diagrams.

Adjourned 10 p.m.

W. W. Horner, *Secretary*.

St. Louis, April 5, 1911.—The 702d meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening at 8.15 o'clock, President Von Maur presiding. There were present forty-nine members and twenty-four visitors.

The minutes of the 701st meeting of the Club were read and approved. The minutes of the 493d meeting of the Executive Committee were read.

Messrs. C. W. Martin, R. L. Williams and L. R. Bowen were elected to membership in the Club.

Applications for membership were read from the following:

Members — R. M. Culbertson, C. O. Thon.

Juniors — Oscar Block.

The report of the Committee on "Wider Organization" was read, and on motion of Mr. Flad was accepted, and the thanks of the Club extended

for the very efficient service of the committee. The committee reported the acceptance by the local organizations of the American Society of Civil Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers, of the Club's proposal for joint action, and recommended the appointment of a joint council who should act on all questions arising between the various societies. The President subsequently appointed the following as the joint council:

Prof. E. L. Ohle, chairman, Am. Soc. M. E.; Mr. O. W. Childs, Am. Soc. C. E.; Prof. A. S. Langsdorf, Am. Inst. E. E.; Mr. W. S. Henry, Mr. H. A. Wheeler, for the Club.

The report of the committee appointed to confer with the Committee of the American Institute of Architects with reference to the bills before the legislature regulating the practice of architects in Missouri, was read and on motion of Mr. Wall was accepted and the committee discharged with the thanks of the Club.

Mr. Brenneke read the report of the committee appointed to consider a schedule of charges for professional services of consulting and construction engineers. On request of Mr. Phillips, Mr. Brenneke read the schedule at length. It was moved, seconded and carried that the report be accepted and the President and Secretary instructed to sign the schedule for the Club.

On recommendation of the Executive Committee the office of Second Vice-President was filled by election at the meeting. Messrs. W. S. Henry, E. L. Ohle and John Hunter were nominated. The ballot resulted as follows:

John Hunter, 18; W. S. Henry, 11; E. L. Ohle, 10.

Mr. A. A. Aegerter, engineer for A. B. Groves, architect, presented a paper on "Some Engineering Features of the St. Louis Building Laws." Mr. Aegerter gave an informal analysis of the St. Louis code, and showed by blackboard demonstration how in many cases modifications could be made which would result in a great saving to the builder, without, in the opinion of the speaker, detracting from the safety of the structure. Mr. Aegerter also stated that one of the standard formulas for bending moment was largely in error, and promised the Club a demonstration of the fact in the near future.

Messrs. Rusch, Flad, Cockran and Talbert participated in the discussion.

The meeting adjourned at 10.30 P.M.

W. W. HORNER, *Secretary.*

ST. LOUIS, APRIL 19, 1911.—The 703d meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, on Wednesday, April 19, 1911, at 8.30 P.M., President Von Maur presiding. There were present thirty members and two visitors.

The minutes of the 702d meeting of the Club were read and approved; the minutes of the 494th meeting of the Executive Committee were read.

Messrs. C. O. Thon and R. M. Culbertson were elected to membership and Oscar Block to junior membership.

An application from W. E. Bryan for transfer from junior to member was read.

Mr. Henry moved that the proposed amendment to Section 2 of the By-Laws be amended so as to include other national societies who might hereafter affiliate with the Club.

Professor Langsdorf offered a substitute amendment, so that the section read as follows:

" BY-LAWS, SECTION 2, *Dues.*— The initiation fee for members and associate members shall be $10.00; for juniors, $3.00. On promotion to the grade of member or associate member, juniors shall pay an additional initiation fee of $7.00. *But the initiation fee shall be waived in the case of applicants who, at the time of their application, shall be members in good standing, and in any grade of membership, of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining Engineers, or such other national society as may hereafter be approved by the joint council of representatives of these societies, and accepted by the Club by majority vote at a regular meeting.*" [Remainder of section unchanged.]

This was accepted by Mr. Henry, and by vote of the meeting Section 2 was amended to read as above.

Mr. Henry moved that the Entertainment Committee be authorized to arrange for a " Got-To-Gether " dinner for the engineers of St. Louis, to cost those attending $1.00, the remainder of the cost not to exceed $2.00 per plate, to be paid by the Engineers' Club. After discussion by Messrs. Brenneke, Ohle, Greensfelder and Von Maur the matter was carried by vote of 21 to 3.

Mr. Elmer A. Hooper, instructor in civil engineering at Washington University, presented a paper on " Experiments with Pitot Tubes, to determine their Action and Efficiency as Static Pressure Meters."

Adjourned, 10.45 P.M.

W. W. HORNER, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MARCH 10, 1911.— A special meeting of the Boston Society of Civil Engineers was held at the Hotel Vendome this evening. The meeting was especially for the purpose of extending a cordial welcome to the ladies and to enable the members who have recently joined the Society to become better acquainted with the older members.

At eight o'clock President Bryant called the meeting to order and introduced Past President Desmond FitzGerald, who gave an exceedingly interesting talk on " Nature Studies in Many Lands," which was profusely illustrated by colored lantern slides.

At the conclusion of the talk, a social hour was enjoyed and a light collation served.

The attendance of members and ladies numbered one hundred and four.

S. E. TINKHAM, *Secretary.*

BOSTON, APRIL 5, 1911.— A special meeting of the Boston Society of Civil Engineers was held at the Boston City Club this evening at eight o'clock.

The students taking the course in civil engineering at Harvard University, at Tufts College and at the Massachusetts Institute of Technology had been invited to be present at this meeting, and about three hundred accepted the invitation.

Mr. Charles T. Main, President of the Society, called the meeting to order and welcomed in fitting terms the guests of the evening.

Mr. George B. Francis, a past president of the Society, gave an illustrated talk on "The Engineering Features of Pennsylvania Terminal Station in New York City."

At the conclusion of the talk, light refreshments were served and a social hour enjoyed, enlivened by college songs by the students. The attendance was about three hundred and fifty.

S. E. Tinkham, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., April 10, 1911.— The fourth regular meeting of the year was called to order at 8.30 p.m. in Society's quarters in Old State Capitol Building, by President L. P. Wolff. There were present eleven members and one visitor.

The minutes of previous meeting were read and approved. Chairman Armstrong of special committee who have in hand the matter of this Society's affiliating with the "Western Society of Engineers" reported that his committee had not been able on account of lack of time to prepare its recommendations, and asked for further time, which was granted.

Chairman Wolff of the "Public Affairs Committee" reported that his committee had considered and recommended that some modifications be applied to "H. F. No. 76," a bill to create a "State Water Supply Commission," now pending before the state legislature.

Mr. Oscar Palmer was appointed a committee of one with full authority to call upon any of the other members to assist him in preparing some sort of entertainment for next regular meeting, which will be held on May 8.

The names of Chas. O. Cook and F. Wm. Fiske, Jr., were dropped from the membership rolls of Society for the non-payment of dues.

The petition of H. LeRoy Brink for full membership in the Society was ordered read and upon motion carried; the Secretary was directed to cast the ballot of the Society admitting the applicant as petitioned; he was declared elected.

Upon motion carried, the "Public Affairs Committee" was directed to interest itself in Mr. Geo. A. Ralph's behalf before the investigating committee of the state legislature, and authorized to take whatever action it deemed proper.

A general discussion of engineering matters was then participated in until adjournment was taken by mutual consent at 10.30 p.m.

D. F. Jurgensen, *Secretary.*

Montana Society of Engineers.

Butte, Mont., March 11, 1911.— The regular meeting for the current month was called to order in the Society room, President Whyte presiding. After the reading and approval of the minutes, the Secretary presented the application of Charles M. Feeney for membership in the Society; said

application was approved and the usual procedure ordered. Messrs. Noble and Garrard were elected to membership by a large and unanimous vote. A letter from Mr. Wm. A. Haven, one of the charter members of the Society, was read and elicited much interest. The chairman of the State Road Committee reported that the legislature failed to take favorable action on the road law prepared by the State Road Law Commission, and stated that he had not been able to learn the real cause of its defeat, but should investigate the matter further. The Secretary read the proposed amendments of the Constitution changing the date of the annual meeting from January to April, and on approval the ballots were ordered sent out, and the members urged to vote, as a majority is required to adopt any amendment. The merits of the American Association for Highway Improvement, recently organized in Washington, D. C., endorsed by President Taft, and having for its president Mr. Logan Walter Page, director U. S. Office of Public Roads, were presented through a letter from the Secretary, Mr. J. E. Pennybaker, and on motion an application for associate membership of the Montana Society of Engineers and an application for regular membership of its Secretary was ordered.

Adjournment followed.

CLINTON H. MOORE, *Secretary.*

BUTTE, MONT., APRIL 8, 1911.— The meeting for the current month was held at the appointed time and place, President F. W. C. Whyte presiding. The minutes of the March meeting were read and received no corrections. The Secretary presented the applications of Jonathan Sewell and Howard Edwin Brillhart for membership in the society, and after approval the usual ballots were ordered.

Charles M. Feeney was elected an active member of the Society. The amendment to the Constitution changing the date of the annual meeting from the second Saturday of January to the second Saturday of April of each year was adopted without a negative vote. Eighty-three votes were counted. Owing to peculiar conditions the dues of Frank A. Jones were remitted for the present year. The Secretary was instructed to mail copies of the Society's year-book to all the county surveyors of the state, with a suitable letter accompanying each book.

Adjournment followed.

CLINTON H. MOORE, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING of the Society, held on Friday evening, March 31, in Room 103, California Hall, University of California, Berkeley, beginning at eight o'clock.

The meeting was called to order by President Dickie.

The Secretary announced the program for the evening, and read a letter from Mr. Willis Polk, in which this gentlemen informs the members that owing to an illness in his family he would be unable to deliver the address which he had promised for this evening.

President Dickie thereupon read a paper entitled: "The Future of Mechanical Engineering," which was a résumé of the engineering of the past, with a view into the future, showing the possible application of engineering to farm work and in the household.

Prof. T. J. J. See, United States Navy, then addressed the meeting, explaining a theory of the cosmogony, of which the underlying principle — which the lecturer illustrated by diagrams — is this: That the planets, and the satellites of planets, were not parts separated from the original nebula, or the parent body, but that they were individual bodies which had been captured, and were held in place by the larger bodies which had attracted and captured them.

Dr. Harker of Australia thereupon explained to the audience a method of extinguishing fires in the holds of ships, by forcing into them waste products from the boiler, thereby reducing the contents of oxygen in the air of the hold from 21 to 15 or 16 per cent., making combustion impossible.

After a pleasant discussion of these topics the meeting adjourned, President Dickie calling attention to the general meeting of the Pacific Association of Scientific Societies, which will take place on April 1, in Room 108, California Hall, University of California.

Otto von Geldern, *Secretary.*

Utah Society of Engineers.

The annual dinner of the Utah Society of Engineers was held at the Commercial Club, Salt Lake City, Thursday, April 20, 1911. Addresses were made by President John Dern, of the American Mining Congress, and by various members of the Society. The following officers were elected to serve for the year 1911-1912:

President, M. D. Grosh; First Vice-President, C. F. Moore; Second Vice-President, E. H. Beckstrand; Secretary, R. B. Ketchum; Treasurer, A. S. Peters.

W. C. Ebaugh, *Secretary.*

Association of Engineering Societies.

Vol. XLVI. MAY, 1911. No. 5.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, April 19, 1911. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President Charles T. Main in the chair. Sixty members and visitors present, including ladies.

It was voted to dispense with the reading of the records of the last meetings and to approve the same as printed in the April *Bulletin*.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members — Messrs. Charles M. Allen, Hiram B. Andrews, Bradford A. Gibson, Edwin C. Hayden, Arthur E. Hoxie, William D. Morrill and Edward F. Rockwood.

Juniors — Messrs. Kenneth P. Armstrong and Sidney S. von Loesecke.

Associate — Mr. Orlando W. Norcross.

He also reported that the Board had elected Mr. Frederic I. Winslow, Librarian, and, under authority conferred at the annual meeting, it had named the following special committees of the Society:

On Excursions: Messrs. C. R. Gow, R. K. Hale, L. E. Moore, H. K. Higgins and J. B. Flaws.

On the Library: Messrs. F. I. Winslow, J. M. Siner, E. R. Olin, G. V. White and H. T. Stiff.

Joint Committee on Club House: Messrs. G. A. Kimball, L. S. Cowles and C. S. Clark.

On Publications and to represent the Society on the Board of Managers, Association of Engineering Societies: Messrs. S. E. Tinkham, Dexter Brackett, C. W. Sherman, G. A. Kimball, H. P. Eddy, A. T. Safford, J. R. Worcester and H. F. Bryant.

The following memoirs were presented and ordered printed in the Journal: Memoir of Louis E. Hawes, prepared by Messrs. G. M. Warren and Erastus Worthington. Memoir of Burton I. Drisko, prepared by L. L. Street.

Before introducing the speaker of the evening, President Main spoke in part as follows:

"I regret that I was unable to attend the annual meeting of the Society and express my thanks for the honor which the Society has conferred upon me by electing me president for the coming year. I now take the first opportunity offered for so doing. I desire to say that I feel highly honored by the confidence which you have placed in me, and I pledge my best endeavors for the best interests of the Society.

"The Society is in excellent condition, in spite of the fact that there is a deficit in the current expense account, but this is not alarming, although it is probable that there will still be a deficit at the end of this year.

"The membership is large and steadily increasing, and each member should do what he can to induce other engineers to join the Society; but numbers alone will not make an efficient body; interest in its affairs and work in the preparation of papers of profit to the profession are necessary to keep up the standard, and I trust that every member will do his share, even if he is not personally urged.

"The Board of Government has been faithful to its charge, and has the welfare of the Society at heart, but cannot alone make a success of the Society. I therefore urge every member to do his share on committee work, in the preparation of papers and the discussion of papers, and if he cannot do any of these things, to help keep up the interest and enthusiasm by attending the meetings. A large meeting is always better than one slimly attended. Let us, therefore, do whatever is in our power to make this not only the oldest engineering society but the best engineering society in the country."

The President then presented Mr. Edwin J. Beugler, who gave a very interesting talk on "Some Byways in Turkey," and had thrown on the screen a large number of views which he had recently taken during a trip through Turkey.

Adjourned.

S. E. Tinkham, *Secretary.*

Boston, May 17, 1911. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President Charles T. Main in the chair. Eighty-seven members and visitors present.

It was voted to dispense with the reading of the records of the last meeting and to approve the same as printed in the May *Bulletin*.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members — Messrs. William D. Hartshorne, Neal J. Holland, Charles A. Leary, Malcolm Rich and Charles M. Taylor.

Junior — Mr. James J. Tobin.

The Secretary submitted the report of the committee, Messrs. C.-E. A. Winslow and Harrison P. Eddy, appointed to prepare a memoir of Leonard Parker Kinnicutt, a member of the society. On motion it was voted to accept the memoir and print the same in the Journal of the Association of Engineering Societies.

On motion duly made and seconded, it was voted that the date and place of the holding of regular meeting in June be left to the Board of Government.

On motion of Mr. Gow, the thanks of the Society were voted to the officials of the Pacific Mills, the Aberthaw Construction Company and the Concrete Engineering Company, for courtesies extended to members of the Society on the occasion of the visit to Lawrence and Haverhill.

At 8.50 o'clock, on motion duly made and seconded, the Society adjourned.

S. E. Tinkham, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., May 8, 1911. — The 5th regular meeting of the year was called to order at 8.30 o'clock P.M., in the Society's quarters in Old State Capitol Building by President L. P. Wolff; there were present fourteen members and eight visitors.

The minutes of the previous meeting were read and approved.

The special committee having in hand the matter of the society's affiliating with the Western Society of Engineers reported as follows:

To the St. Paul Society of Civil Engineers, St. Paul, Minn.

Gentlemen, — We, a committee appointed to investigate and report on the advisability of dropping our membership in the Association of Engineering Societies and becoming a branch of the Western Society of Civil Engineers respectfully report as follows:

Our Society now has a membership of over ninety, and some are very prominent in the engineering profession. We have a good up-to-date library and our Society is in good standing. Whilst we have not published a great many papers in the Journal of last year, we have had very instructive lectures, which have been of great benefit to the members. Of course, these lectures do not appear in the Journal, but they were very instructive nevertheless.

We are members of the Association of Engineering Societies comprising societies in eight large cities of the United States, making us practically members of a society numbering 2 000 or more. Our Association publishes a very valuable journal, thoroughly up-to-date in recording the doings of different members of the Association from the Atlantic to the Pacific oceans, and keeps us posted on works going on all over the country. As individual members of any of these societies we can by a transfer without additional expense become a member of any of the eight societies mentioned.

We are well aware that the Western Society embraces in its membership very active and thoroughly up-to-date engineers in all lines. It has a membership of something over 1 100, largely in Chicago. It publishes a thoroughly up-to-date engineering journal, in which appear very valuable papers from very able men. However, should we become a branch of the Western Society, all our members who would join would be obliged to pay the initiation fee and dues to that society, besides keeping up the expenses of their own branch, and no doubt a large number of the present members in the St. Paul Society would refuse to make the change.

Taking everything into consideration, your committee fails to see wherein any benefit would be derived from the change, and recommends that we remain in the Association to which we now belong.

Very respectfully submitted,

J. H. Armstrong.
Harry C. Palmer.
Adolph F. Meyer.

Upon motion carried, the report and recommendations of the committee were adopted, and it was the further sense of the meeting that the Society remain as it now is.

At the conclusion of business the entertainment committee were given charge, and a most delightful program, consisting of legerdemain, popular

musical numbers by Colestock's Orchestra, concert numbers by the new Columbia Grafanola, and refreshments were enjoyed by those present.

Adjournment was taken by mutual consent at 10.30 P.M. until October 9, next.

D. F. JURGENSEN, *Secretary*.

Association of Engineering Societies.

Vol. XLVI. | JUNE, 1911. | No. 6.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, May 17, 1911. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President Charles T. Main in the chair. Eighty-seven members and visitors present.

It was voted to dispense with the reading of the records of the last meeting and to approve the same as printed in the May *Bulletin*.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named :

Members — Messrs. William D. Hartshorne, Neal J. Holland, Charles A. Leary, Malcolm Rich and Charles M. Taylor.

Junior — Mr. James J. Tobin.

The Secretary submitted the report of the committee, Messrs. C.-E. A. Winslow and Harrison P. Eddy, appointed to prepare a memoir of Leonard Parker Kinnicutt, a member of the Society. On motion it was voted to accept the memoir and print the same in the Journal of the Association of Engineering Societies.

On motion duly made and seconded, it was voted that the date and place of the holding of regular meeting in June be left to the Board of Government.

On motion of Mr. Gow, the thanks of the Society were voted to the officials of the Pacific Mills, the Aberthaw Construction Company, and the Concrete Engineering Company, for courtesies extended to members of the Society on the occasion of the visit to Lawrence and Haverhill.

At 7.50 o'clock, on motion duly made and seconded, the Society adjourned.

S. E. Tinkham, *Secretary.*

At the conclusion of the regular meeting of the Society, a joint meeting was held in coöperation with the American Society of Mechanical Engineers and the Boston Section of the American Institute of Electrical Engineers, the program of the evening being in charge of the latter organization.

A paper on " The Electric Motor in the World's Work " was presented by the author, Fred M. Kimball, manager of the Small Motor Department of the General Electric Company, West Lynn, Mass., in which he briefly de-

scribed the development of the electric motor from the discovery of the fundamental principles early in the nineteenth century up to the present time. He exhibited a large number of lantern slides showing the very diversified application of the motor to various industries. On account of the character and length of the paper there was no discussion. The attendance was about 150.

JOURNAL

OF THE

Association of Engineering Societies.

ST. LOUIS. BOSTON. ST. PAUL. MONTANA.
PACIFIC COAST. DETROIT. LOUISIANA.
UTAH. OREGON.

CONTENTS AND INDEX.

VOLUME XLVII.
July to December, 1911.

PUBLISHED MONTHLY BY

FRED. BROOKS, SECRETARY OF THE BOARD OF MANAGERS OF THE
ASSOCIATION OF ENGINEERING SOCIETIES.
31 MILK STREET, BOSTON.

CONTENTS.

VOL. XLVII, July–December, 1911.

For alphabetical index, see page v.

No. 6. DECEMBER.

INDEX.

VOL. XLVII, July — December, 1911.

ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors are printed in *italics*.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVII. JULY, 1911. NO. 1.

THE EMSCHER SEWERAGE DISTRICT AND THE IMHOFF TANK.

BY CHARLES SAVILLE,* MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Presented to the Sanitary Section, December 28, 1910.]

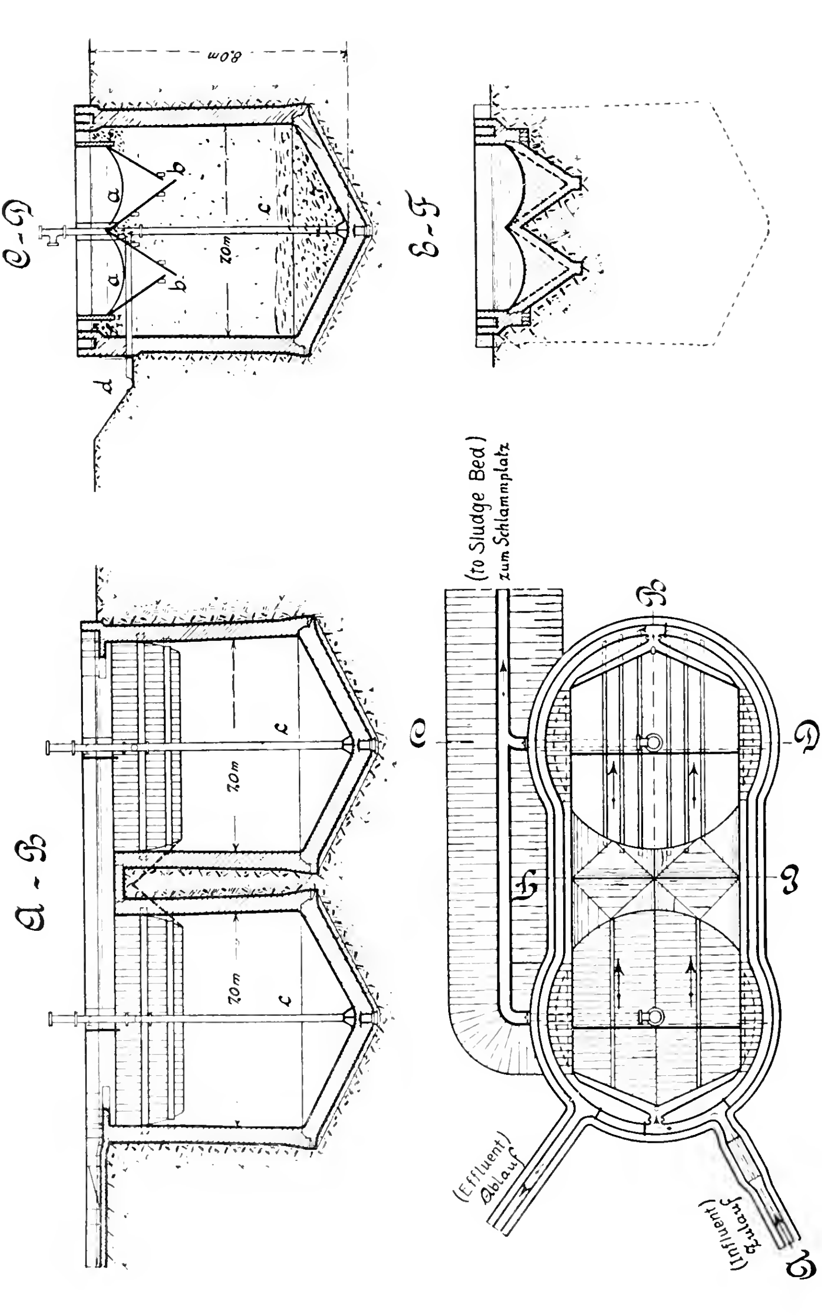
THE writer has recently had the good fortune to travel in Germany, England and France in company with Dr. Rudolph Hering, of New York, and Prof. Frederick Bass, of the State Board of Health of Minnesota, and to visit many interesting plants for the purification of both sewage and drinking water. In the present paper I will first mention a few of the more important things we noted during the trip, and then describe the work I have been engaged in during the past four months in the vicinity of Essen, Germany, where some interesting methods of sewage treatment for preventing the pollution of streams are now in use. Articles describing this work have been published in the *Engineering News* † and the *Engineering Record*.‡ Those who are interested in looking into the matter further can find considerable data there, some of which I shall not attempt to duplicate in the present paper.

In regard to water purification, one of the most noticeable things which came to our attention in Germany was the use of chemicals in connection with slow sand filters. The water filters

* Emschergenossenschaft, Essen, Germany.

† December 1, 1910.

‡ December 10, 1910.



SKETCH OF IMHOFF TANK INSTALLATION.

both in Bremen and Hamburg did not always give good results at times when the river water contained much fine clay. Even at Bremen, where they have double filtration, this fine silt, as well as bacteria, sometimes passed through the filters. The use of alum in connection with these filters makes possible much better results, and the people are thoroughly satisfied with the treatment. In Germany they are also beginning to talk a little about the treatment of water with hypochlorite of lime. I know of no plants in operation, but some experiments are being made on a large scale in the vicinity of Essen. Perhaps in the near future we shall have some data showing whether this method of treatment is as applicable to German conditions as to those here in America.

We heard quite a little about the purification of water through the help of the so-called "ultra-violet rays." This treatment is being experimented with at the Royal Testing Station in Berlin, and quite a little work of the same nature has been done in the vicinity of Paris. At the present time one can say very little about it. It is still in the experimental stage. Considerable is claimed for the treatment, however, much the same as with ozone. It may prove too expensive, and at the present time the certainty of the destruction of bacteria by "the rays" is not absolute. I do not know of any plants that are being operated on a practical scale. The ozone treatment, of course, is still being used to a certain extent, but one or two of the best plants, which have had a good deal said about them in former years, have gone out of commission, owing, I think, to a combination of high cost of operation and rather unsatisfactory results.

At Madgeburg, Germany, there is an interesting system of water filtration, spoken of as the Puech system, where water is filtered through five sets of coarse-gravel filters, then through what are called rapid sand filters, — ordinary sand filters operated at a very high rate, — and finally through slow sand filters similar to those at Lawrence. The final effluent is exceptionally clear as a result of all this filtration, but the operating expenses are said to be high. There are one or two other similar plants operating in Germany

In the realm of sewage purification, one of the newest things being experimented with is the treatment of sewage sludge by centrifugal machines. There is now a good plant operating at Hanover, and another at Harburg. We saw the former, but not the latter. The centrifugal machines at Hanover produce a

comparatively dry, but somewhat odorous, sludge. One of the weakest points about the treatment, however, is the fact that the liquid separated from the sludge during its treatment in the centrifugal machines is objectionable in character, and, if turned back into the settling tanks, is likely to bring about a septicization of the sewage. At Hanover the result was so objectionable that they were at one time forced to turn this liquid directly into the river. The treatment is, of course, expensive. It is being used at Frankfort, where they plan to burn the dry sludge in the city refuse incinerator.

It is well known that large sewage screening plants are quite common in Germany. There is one at Dresden which has but recently been completed. It represents an extremely large outlay. Many of the German screens, particularly the one at Hamburg, do good work in removing the larger suspended solids, i. e., everything that would tend to float. But some of the screens, as now operated, do not strain out the finer suspended solids, particularly if there is a head of water on the screen. We noticed in places that a considerable portion of the finer material always went through the screen. In certain cases this may not be particularly important, if the sewage goes directly into a large body of water, as at Hamburg.

The treatment of sewage by chemical precipitation is still being used in many places. There are two or three large plants in Germany, and in England a very large new plant has been started recently in the city of Leeds. This is, perhaps, worthy of note, when we stop to think that in the United States the general tendency has been away from — rather than in favor of — treatment with chemicals. At Salford, we found that the use of chemicals in the settling tanks led to the formation of deposits in the percolating filters, causing much trouble.

People are everywhere losing interest in the "septic" tank, due principally to two things: First, because the effluent usually contains a considerable quantity of fine suspended matter, resulting from the stirring action of the gas in the deposited sludge; second, because the sewage in passing through the tank becomes septic as a result of its contact with the sludge and with the gases given off during decomposition. Most of the engineers with whom we spoke were in favor of keeping sewage as fresh as possible previous to its final treatment on biological filters.

At Hanley, England, where the sewage is treated in septic tanks and subsequently purified on percolating filters, a very good effluent is obtained, due partly, perhaps, to the fact that the

sewage contains certain ingredients which act as precipitants and throw out in the tanks a large proportion of the organic matter. Six or seven cities and towns in this vicinity have united to handle their sewage disposal problems together, and employ an engineer to take charge of that work. This is another indication that such questions can sometimes be handled more economically when a number of municipalities located in the same drainage area work together under the direction of an experienced engineer.

Much has been said of the hydrolytic tank operated in Hampton. It will be remembered that the tank has two principal features. One is the automatic removal of the deposited solids from the portion of the tank which has the sewage flowing through it. The other is the presence of so-called "colloiders" in the sedimentation chamber. The sewage coming in contact with these colloiders is supposed to leave on them a certain part of the organic matter carried in solution. I visited the plant at Norwich which is built on this principle. So far as could be seen from a single visit, the colloiders evidently remove from the sewage more of the organic matter than would settle out naturally of itself. But the colloiders, instead of being self-cleansing, retain much of the material removed from the sewage. As a result, the sewage which was passing between the colloiders and coming in contact with this deposited matter became septic. The effluent of the tank contained much suspended matter and was quite foul.

The Emschergenossenschaft.

The most interesting subject we found in Germany was the commission (located in the vicinity of Essen) spoken of as the *Emschergenossenschaft*. The word "*Genossenschaft*" means federation, — a federation of the cities and towns, the coal mines, the steel and other industries, and the farming interests in the valley of the Emscher River. This river is a small tributary of the Rhine. The population included within the drainage area is approximately 2 000 000. The largest city is Essen, with 300 000 inhabitants. There are also a number of cities having a population of more than 50 000, besides many smaller places. In this district, which embraces about 300 square miles, there are also more than 200 coal mines as well as a great many steel and iron works.

The coal mines extend very deep beneath the surface, but,

as a result of poor bracing, and from other causes, there is in many parts of the district a gradual settling of the ground, which interferes with the drainage facilities. The rivers and streams have for many years been seriously polluted by wastes from the coal mines and from the steel and iron works, as well as from the cities and towns. The conditions gradually became very objectionable; but the individual municipalities did not take the necessary steps to check or stop the pollution. Finally the people in the lower reaches of the valley went to the Prussian government and obtained a special act providing for the formation of this commission, or Genossenschaft, so called.

It has about one hundred members, the steel works, the coal mines and farming interests being represented, as well as the cities and towns. There are also a certain number of representatives of the Prussian government. The first work of the Genossenschaft was to make a careful survey of the entire valley, then to design, construct and operate such works as should be necessary to dispose of the sewage and to provide and maintain proper drainage throughout the valley.

It was formed in 1904 and started work shortly afterward. At the present time a large amount of work has been accomplished. The organization is particularly interesting, because its powers are not what might be called advisory. The Genossenschaft actually does the work. It makes the surveys and designs the sewerage systems. It designs the new channels for the streams, also the sewage purification works. And then it builds all these works — or, rather, the work is done by contractors, but the Genossenschaft has full supervision over it. After the works are completed it has full charge of their operation. This refers to the main sewers common to more than one city or town, to the purification works, and to the tributaries and the main channel of the Emscher River. In addition, the Genossenschaft decides who shall pay for the work. It is empowered to borrow money and to assess the cost of construction and maintenance on the cities and towns and on the other interests in the valley.

In assessing these costs, the main considerations are, first, who is responsible for the objectionable conditions which must be improved, and, second, who will benefit the most from the proposed changes. If the interested parties are not satisfied with the division of the expenses, there is a special committee of the Genossenschaft to which they can appeal. This committee includes representatives from the Prussian government. The committee makes the final decision from which there is no appeal.

It works out very nicely in practice, and, as already mentioned, the Genossenschaft has been in existence now for six years.

There are five departments, three of which have charge of the "regulation" of the main stream and its principal tributaries. The fourth department designs and supervises the construction of all bridges. The fifth department builds and operates the sewers and sewage-disposal works.

For the last four months it has been my good fortune to be connected with the sewerage department, of which Dr. Imhoff is the chief.

In connection with the work of this department, there are two things of special interest to be spoken of. The first is the question of sewage disposal by "dilution," as it is being worked out in this district. The second is the special type of sewage-clarification tank which has been developed and perfected under Dr. Imhoff's supervision.

Sewage Disposal by Dilution in the Emscher District.

There will eventually be more than fifty sewage purification plants in the drainage area of the Emscher River. At the present time only seven are in operation. The oldest has been running about four years. Of these seven only two include treatment other than the clarification of the sewage. Two small towns situated at the head of poorly regulated streams are provided with so-called biological or percolating filters in addition to the tanks which remove most of the suspended solids from the sewage.

The results (with respect to the pollution of the streams) would perhaps be rather questionable if the clarified sewage were

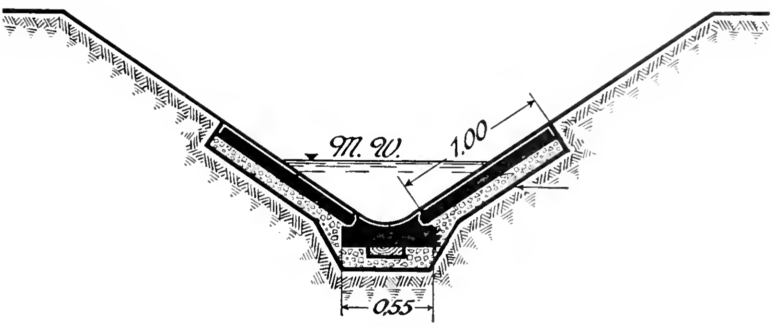
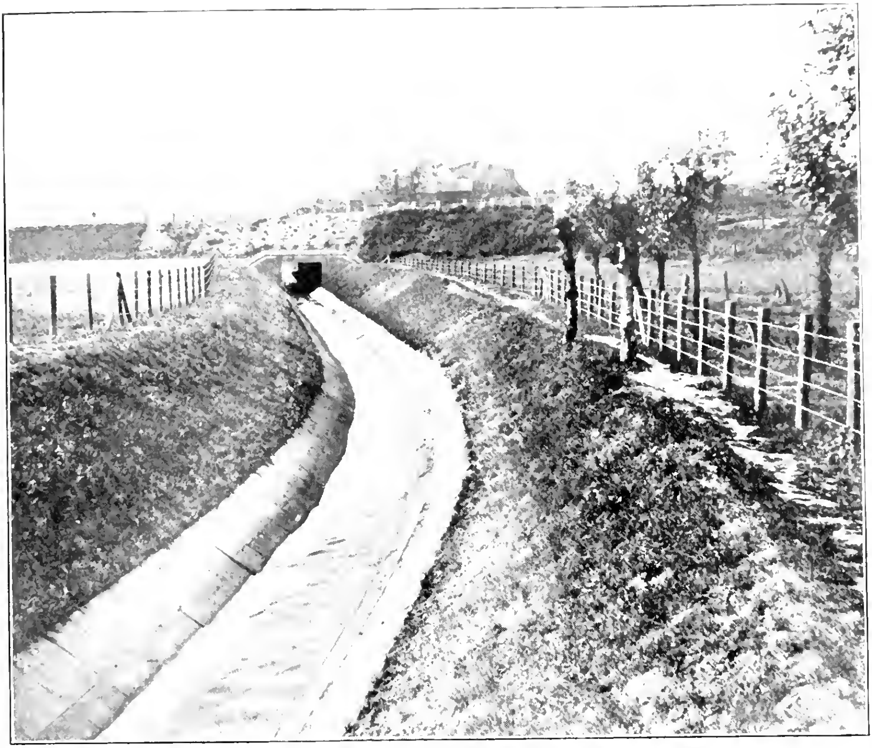


Fig. 1. Cross Section through Typical Open Canal.
(Dimensions in meters.)

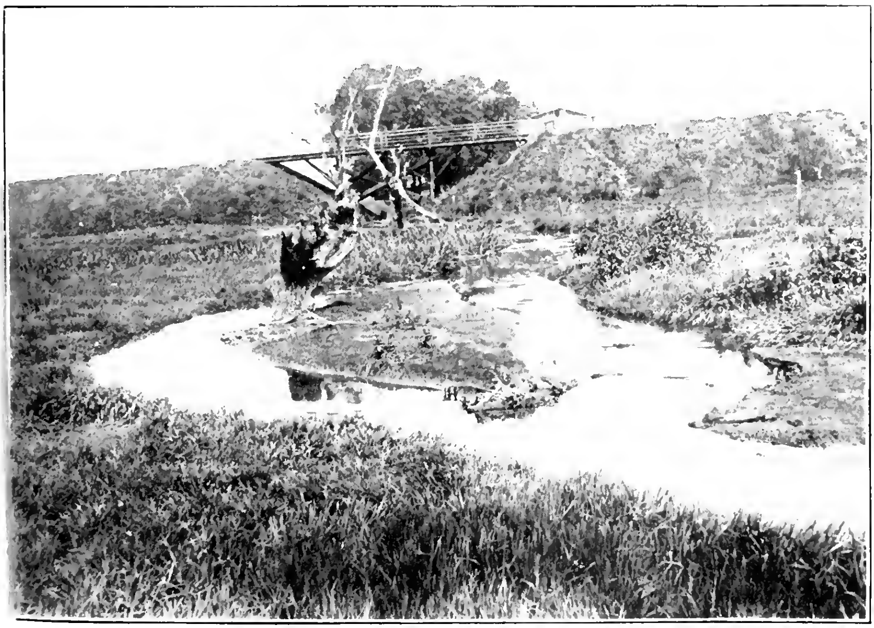
to be discharged into water courses which were not properly regulated. But the engineers of the Genossenschaft have recognized the fact that the "dilution" is not so important as the condition of the streams receiving the sewage discharge, and are therefore providing for improvements of many of the tributaries of the Emscher as well as the main river itself. A cross section of the channel used for most of the smaller streams is shown in Fig. 1. The channels are built with good grades and smooth surfaces. They are lined with concrete blocks. Sewage, after entering the channels, will have a rapid flow all the way to the Rhine. The Rhine is, of course, a very large stream, and although it contains much dirt and receives a great deal of pollution, it is not objectionable at the present time even in very dry weather.

The engineers of the Emschergenossenschaft believe that if the coarser suspended matters are removed from the sewage, and if the channels are properly regulated, there will be no nuisance. It is a little hard to say now whether this will prove to be the case. The work will probably be completed in 1914 or 1915. Then will be a good time to decide whether "disposal by dilution," as it is being worked out in this district, will be successful or not. They believe in it very strongly at Essen, and it certainly looks as if the results would be satisfactory. I have seen many of the smaller streams, which are practically unpurified sewage. The water flows in the smooth channels with a good velocity and there is no obje tionable odor or deposit, even though much of the sewage as it enters the streams from the cities and towns is quite septic, due to the general use of cesspools. It might be of interest to mention that the minimum mean velocity of average flow in the smaller streams is figured at about 2.3 ft. per second. These open channels are used for many of the main sewers outside the thickly settled portions of the cities and do not give rise to objectionable conditions.

The annual rainfall in the vicinity of Essen is about thirty inches, distributed evenly throughout the year. And perhaps the variation in the volume of water flowing in the streams is not so great, or the dry-weather flow so small, as we find in many parts of America. Under present conditions the minimum average flow in the Emscher for any one month is approximately 190 cu. ft. per second, about one third of which consists of sewage and trades wastes from a population of 1 500 000. The remainder is made up of coal-mine drainage, together with small amounts of ground water. At the present time less than thirty per cent.



A Tributary of the Emscher River after Regulation.



A Tributary Similar to the Above before Regulation.

of the sewage is clarified before being discharged into the streams.

The Imhoff Sewage Clarification Tank.

The clarification tank adopted for treating sewage in the Emscher district has been generally referred to in this country as the Emscher or Imhoff tank. It was perfected by Dr. Karl Imhoff, chief of the sewerage department of the Emschergenossenschaft. So much has been said about the tank of late that some people already appear to think too much is claimed for it. This is perhaps unfortunate, and it may be well to emphasize the fact that the tank is in no sense a complete method of sewage purification.

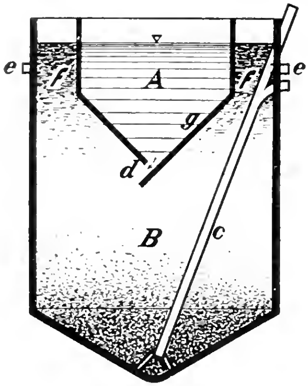
Engineers are familiar with the popular fallacy that so-called "septic tanks" render sewage pure. The Imhoff tank — like the septic tank or other sewage-treatmen tanks — does not render sewage "pure." It has to do principally with but two steps in the process of sewage purification, — first, clarification of the sewage; second, treatment of the sludge.

A large part of the more objectionable impurities in sewage is carried by the water in suspension. The dissolved organic matter can usually be more readily purified after the suspended solids have been removed. It is, therefore, desirable to separate this suspended matter completely from the sewage and dispose of it separately. After removal from the sewage it is referred to as "sludge." The clarified sewage may, under certain conditions, be discharged directly into natural water-courses. If necessary it can be further purified by filtration. In either event the separated sludge should be disposed of in such a manner (1) that it shall not again come in contact with the clarified sewage, and (2) so that no nuisance shall be produced.

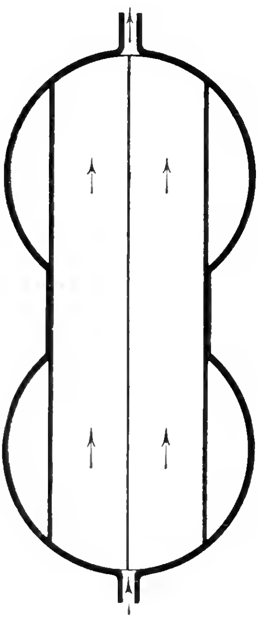
The best method of effecting this separation of the sewage and the sludge, with suitable provision for a satisfactory treatment of the latter, has for a number of years been carefully studied by engineers and chemists; but without entire success. Separate sludge-decomposing tanks were tried at Lawrence, and more recently a sewage-treatment tank has been operated on a larger scale in Hampton, England, whi h provides an automatic removal of the deposited sludge into another department of the tank for subsequent decomposition. The Imhoff tank is a development of this Hampton (or Travis) tank. It is shown in its simplest form in Fig. 2.

The sewage passes through the sedimentation chamber (*A*)

Fig. 2.

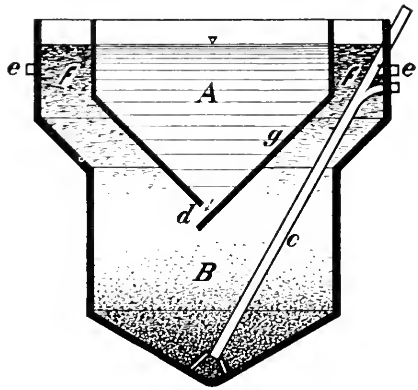


Section.

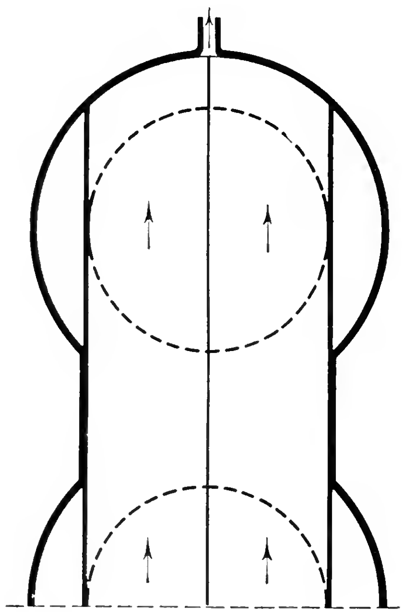


Plan.

Fig. 3.



Section.



Plan.

in a direction perpendicular to the plane of the drawing. The suspended solids gradually settle out and slide down the sloping bottoms (*g*), finally passing through the openings (or "slots") (*d*) into the sludge-decomposing chamber (*B*). The sludge remains in this chamber until its putrescible organic matter is

thoroughly decomposed, being then removed from the bottom through the pipe (*c*). The suspended matter which settles out of the sewage is thus removed automatically and completely. The gases of decomposition, which are largely inodorous, escape at (*f*). These gases, as well as the rising particles resulting from the decomposition of the sludge, cannot come in contact with the flowing sewage because the bottoms (*g*) of the sedimentation chamber are so overlapped at the slots that this is impossible. These slots form the only connection between the sedimentation chamber and the sludge-decomposing chamber. There is no outlet to the latter (except through the sludge pipe) and no flow of sewage into or through it.* The sewage stands at the same level in both chambers. As a result of its passage through the sedimentation chamber the sewage becomes well clarified and at the same time remains fresh. The sludge, on account of its low water content and the decomposition of much of its organic matter, is comparatively small in amount, dries quickly and is unobjectionable.

This, in brief, is the theory of the working of the tank. Its advantages over an ordinary so-called septic tank are easily appreciated. In the latter the flowing sewage is in contact with the gases and suspended particles rising from the decomposing sludge on the bottom of the tank, the result being that the effluent is septic, it is more liable to have a disagreeable odor, and often contains much fine suspended matter. These characteristics usually make subsequent purification more difficult. On the other hand, the sludge removed from a "septic tank" may, in some instances, be practically as satisfactory as that taken out of Imhoff tanks provided all of the putrescible organic matter has been completely decomposed.

Imhoff tanks were first used on a practical scale at Recklinghausen, Germany, a city of 30 000 inhabitants situated near the source of a small tributary of the Emscher River. This plant has been in operation four years. The Emschergenossenschaft has now 7 other similar installations, serving altogether a population of 250 000, while as many more are in process of construction. Within another four or five years the sewage from most of the 2 000 000 people in the valley of the Emscher River will be

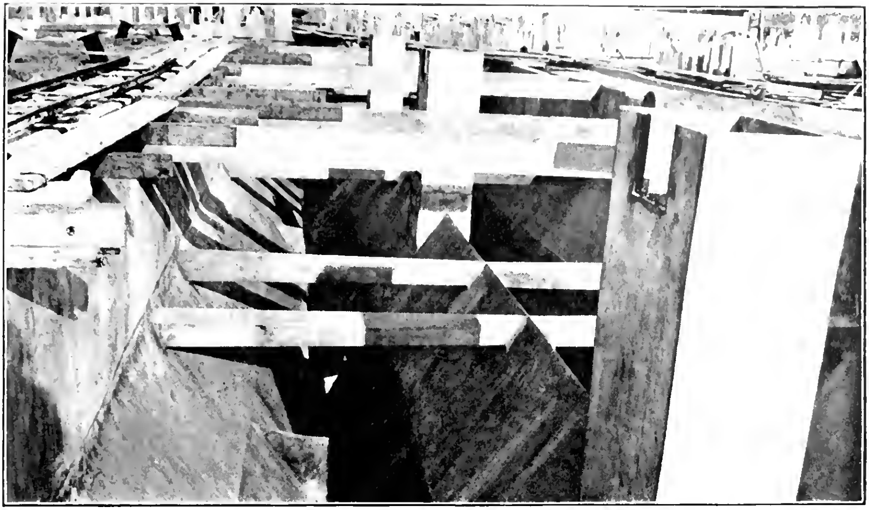
---

* In the Travis tank as operated at Hampton there is an outlet to the sludge chamber which is so arranged that about one fifth of the total flow of sewage entering the sedimentation chamber passes down through the slots and through the sludge chamber — where it becomes septic — to the effluent channel.

treated in these tanks. The tanks are also being used in many other parts of Germany. In most cases, however, they have only recently been placed in operation. In the United States a large installation is now being built at Atlanta, Ga., and smaller plants are proposed for a number of other cities.

In 1908 the operation of the tanks in the Emscher district was studied by Dr. Rudolph Hering, of New York, who visited a number of the works during the summer. Being favorably impressed with the results thus far obtained, he shortly afterward recommended the installation of an experimental tank at Philadelphia. Mr. H. W. Clark, of Lawrence, was also in Europe in 1908, and on his return to America referred to the Imhoff tank in a paper read before the Boston Society of Civil Engineers on October 7. The results obtained with the Philadelphia tank were so satisfactory that it was decided to build similar tanks on a large scale as a part of the proposed disposal works at Torresdale on the outskirts of the city. This plant is now in process of construction. It is described in the *Engineering Record* of January 14, 1911. Meanwhile a second experimental tank had been started in Chicago at the testing station of the Sanitary District, and the reports from the German installations continued to be so good that Dr. Hering determined to visit them again. He was accompanied this time by Professor Bass, of the University of Minnesota, and myself. We examined many of the more important sewage disposal works on the continent and in England, but found nothing that aroused our interest to the same extent as the sewage clarification tanks built and operated by the Emschergenossenschaft. Dr. Hering was even more pleased with the results being obtained than had been the case two years previous. Both Professor Bass and myself were very favorably impressed. A single examination of two or three plants, however, is at best somewhat unsatisfactory so I was glad to have the opportunity of remaining in Essen and studying the matter thoroughly at first hand.

My work during the past four or five months has brought me closely in touch with all the sewage-disposal works in the Emscher district. I have had something to do with the design and construction of new installations, and have been able to watch the operation of the older plants under various conditions. It has thus been possible to learn much about the tanks — their weak points as well as their good points — and their applicability to our conditions here. With the experience thus far available, it would seem safe to predict that this style of tank, when properly

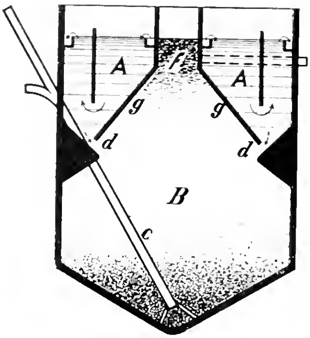


Horizontal Flow Tanks (during Construction).

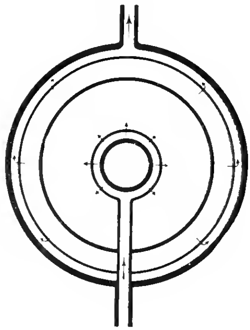
The sedimentation chamber consists of two V-shaped troughs as in Fig. 6. Shafts for scum and rising gases are shown above the center of each sludge well.

Horizontal Flow Tanks.

Fig. 4.

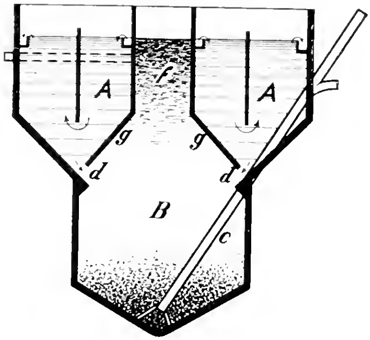


Section.

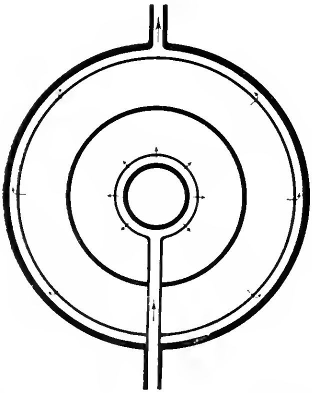


Plan.

Fig. 5.



Section.



Plan.

Radial Flow Tank (during Construction).
The circular baffle is hung from two I-beams. See Figures 4 and 5.

designed with due respect to local conditions and when intelligently operated, will be found very effective in America as a means of clarifying sewage and providing a satisfactory treatment for the deposited sludge.

Design and Construction.

Although the principles on which these tanks are based are simple and easily understood, the tanks should be carefully designed. This becomes specially important when it is remembered that sewage-disposal works are often sadly neglected or operated by persons having no proper training.

The tanks are usually built as deep circular wells twenty-five to thirty feet in diameter and 20–25 feet deep. A deep tank is likely to give better sludge because more gas is developed per square foot of horizontal cross-section than in shallow tanks. This gives a better stirring action to the decomposing sludge. And the sludge after decomposition is permeated with small gas bubbles held there (so long as the sludge remains in the tank) by the pressure of the water above. With deep tanks there is a more uniform temperature in the sludge-decomposing room, and it might be mentioned here that as large a proportion as possible of the total depth of the tank should be below the slots. These slots — in deep tanks — are comparatively short with respect to the total volume of the tank and there is practically no tendency for currents to develop between the sedimentation and sludge-decomposing chambers. The circular form has been adopted because with deep tanks it is cheaper to build, especially if there is much ground water or quicksand.

The sedimentation chamber may be arranged for a horizontal flow as shown in Figs. 2 and 3, where the flow is at right angles to the plane of the drawing, or for a radial flow — Figs. 4 and 5 — where the conditions of flow are somewhat similar to those in a so-called Dortmund tank. With horizontal-flow tanks the sedimentation chamber may be continuous over two or three sludge wells, and in such cases the inlet and outlet weirs are so arranged that the flow can be periodically reversed. This gives a sludge of uniform character in each of the wells. The horizontal-flow sedimentation chamber is perhaps best for large plants or where there are large variations in the quantity of sewage, such as we find in many American cities. In radial flow tanks the velocity with which the sewage passes through the sedimentation chamber is an important factor in the sedimentation of the sus-

pended matters. In the portion of the chamber where the flow (after passing under the baffle) is vertically upwards the velocity should be less than 1 millimeter per second.

In each of the sketches (Figs. 2, 3, 4 and 5) the cross-hatched portions of the tank "A" represent the sedimentation chamber. The rest of the tank is devoted to sludge decomposition. It will be noticed that in Figs. 2 and 3 the sludge-decomposing chamber extends up on both sides of the sedimentation chamber. In the radial flow tanks (Figs. 4 and 5) the upper part of the sludge chamber is an annular space in the center of the sedimentation chamber. In both cases the upper part of the sludge-decomposing chamber (shown at *f*) serves as an outlet for the rising gases and provides space for floating sludge particles which have been stirred up and have risen under the action of the gases. Scum-pipes, shown at (*e*), are sometimes provided for removing floating sludge if this becomes necessary. Certain kinds of sludge have a tendency at times to float, and the space (*f*) above the slots should be large enough to prevent its overflowing into the sedimentation chamber or working back into this chamber from below through the slots. This consideration may not be found important with weak sewages; but in general it is well to err on the side of having too much space for the floating sludge (or scum) instead of too little. In the plants of the Emschergenossenschaft the portion of the sludge-decomposing chamber located above the slots is one half to two thirds as large as the portion below the slots. To have nothing but small ventilation pipes for the gases is not likely to be sufficient.

The relative size of the sedimentation and sludge-decomposing chambers depends on the character and strength of the sewage as well as the quantity to be treated. The former is usually designed to give a period of sedimentation for the dry-weather flow of from one to two hours — seldom as long as three hours, even with a weak sewage. At times of storm the tanks treat three or four times the dry-weather flow. The portion of the sludge-decomposing chamber below the slots should be large enough to provide a decomposing time of at least two or three months. It is usually designed to hold an accumulation of sludge (in a thoroughly decomposed condition) representing deposits entering from the sedimentation chamber during a period of six months or more. The volume of the sludge (after decomposition) has been found in the Emscher district to be about 0.1 liter per head of population connected with the tanks per day. This figure refers to a "separate" system of sewers which does not

receive exceptionally large amounts of trades wastes. With a combined system of sewers the quantity of sludge per capita is figured at double the above amount. With a dilute sewage having large variations in flow and a comparatively small amount of sludge the tanks would be designed somewhat as shown in Fig. 3, or, for radial flow, in Fig. 5. But for a strong sewage containing much suspended matter, as is the case in many German cities, the tanks would be built as shown in Figs. 2 or 4. The depth of the tanks is the same, whether the sewage be strong or weak; but as is evident from the figures, the sludge-decomposing chamber must form a larger per cent. of the entire tank when the sewage to be treated contains much suspended matter than is the case if the sewage is comparatively dilute. A large sludge chamber has the important advantage that the decomposed sludge may be allowed to accumulate in it until the weather is most favorable for drawing out and drying the sludge.

The slots between the sedimentation and the sludge-decomposing chambers are 6 to 8 in. wide. The sides and bottoms of the sedimentation chamber must be smooth so that the deposited sludge will slip easily towards the slots. They should be air-tight so that the gases of decomposition cannot work through them into the flowing sewage. They ought also to be strongly built so as not to warp or crack. Both wood and concrete have been used, the slope of the bottoms being 1.5: 1. Iron and zinc are likely to be attacked by the gases and sewage in the sludge-decomposing room and have proved unsatisfactory. There must be sufficient overlap at the slots to prevent all possibility of gas bubbles and sludge particles rising from the sludge room into the sedimentation chamber.

The inner surfaces of the sludge chamber are made smooth, and the main walls of the tank are built with a slight batter (the diameter of the tank being greatest at the bottom) so that there will be as little opportunity as possible for sludge to stick to them. The sludge pipe shown at (*c*) in Figs. 2 to 5 should be about 8 in. in diameter. It has a bell mouth at the lower end, and is elevated a foot or more above the bottom of the tank, which is built as an inverted cone with a smooth surface sloping towards the center. Small perforated water pipes are placed around the bottom of the well and near the mouth of the sludge-pipe, so that if necessary the sludge may be loosened by forcing water under pressure into it. A connection with the water mains is also provided at the upper end of the sludge-pipe. It has been

found that with a tank 25 or 30 ft. deep a head of 3 to 4 ft. is necessary to force the sludge easily out through an 8-in. pipe.

The sedimentation chamber should be kept as free as possible from pipes, braces, etc., which might collect and hold small amounts of sludge, thus making the sewage septic. Necessary pipes and horizontal surfaces must be pointed up with cement so that the suspended matters as they settle will slip readily off and pass down through the slots into the sludge room. Baffle-boards in the sedimentation chamber are necessary to prevent floating matters passing out with the effluent, and when properly designed

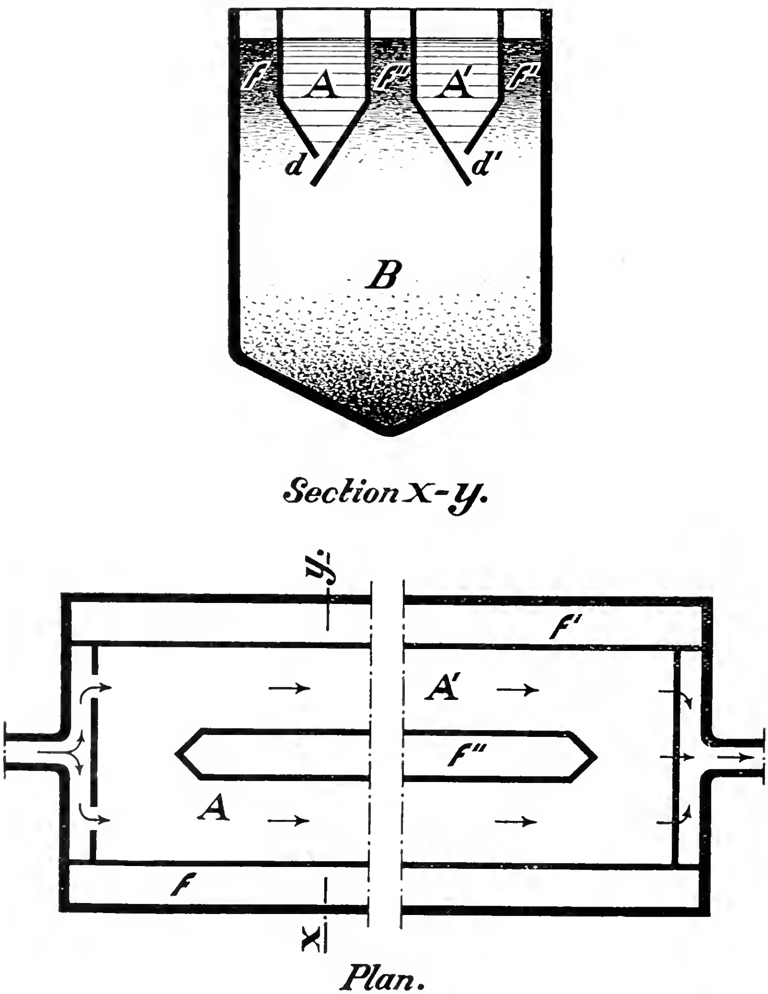


FIG. 6.

will so guide the flow of the sewage as to make effective the entire chamber. They should not be carried too deep, however, because the quiescent sewage just above the slots will then be disturbed by the current.

Although the circular type of tank has been used almost exclusively in Germany, it is perfectly feasible to build rectangular tanks. In some instances old rectangular tanks, after being operated for a number of years as septic tanks, have been remodeled according to the Imhoff idea simply by the installation of the necessary division walls. The sedimentation chamber of such a tank may be arranged in two parts (A and A') as shown in Fig. 6, which is a cross-section at right angles to the sewage flow. With an arrangement of this sort there is space (f'') for a gas outlet and for accumulations of floating scum, in the center as well as at the sides (f and f'). The important thing to consider here is that the space (f'') must not extend the entire length of the tank. It is essential that the two sections of the sedimentation chamber (A and A') shall be connected (preferably at both ends). Otherwise an uneven distribution of the flow between them could give rise to currents through the sludge-decomposing room (B) from one row of slots (d) to the other (d').

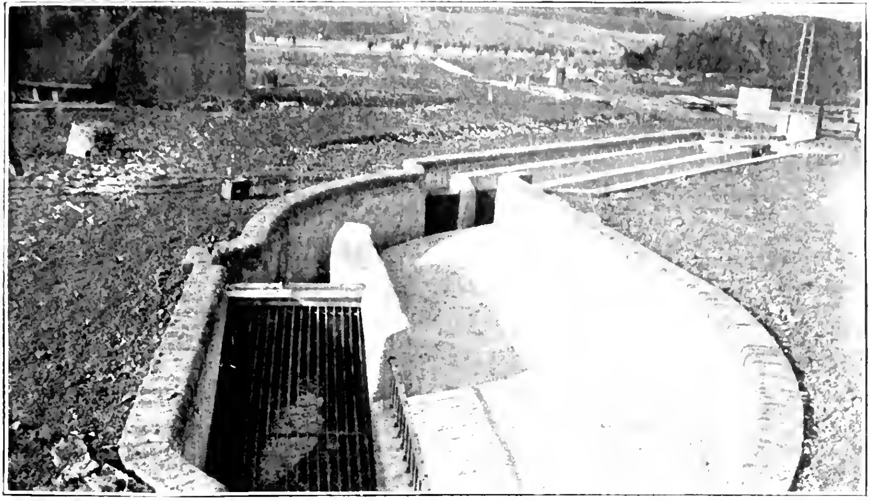
Operation.

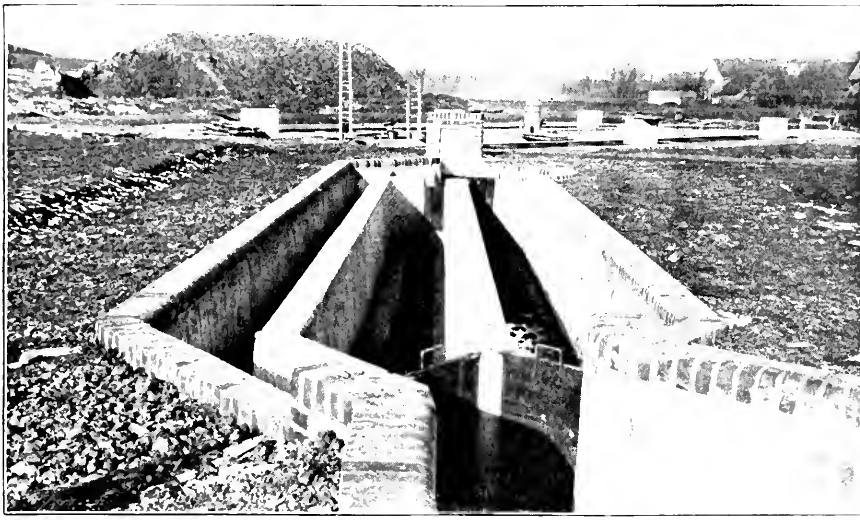
The sewage-disposal plants operated by the Emschergenossenschaft serve populations varying between 2 000, for which a single clarification tank is sufficient, to 150 000, requiring eighteen tanks. The various disposal works have recently been described in detail by H. Blunk, operating engineer, and Dr. Spillner, chemist, of the Genossenschaft, in the *Technisches Gemeindeblatt* for January and February, 1911.

At some of the plants the sewage is purely domestic and contains little surface water, as the sewers are built on the separate system. In the larger cities the combined system is used and the sewage contains trades wastes including some coal-mine drainage which has already been treated by sedimentation for the removal of the coal sludge. There is a certain amount of sulphur in this mine drainage. The trades wastes are of various sorts; but come principally from gas works and iron works. In only one or two instances, however, are there large amounts of iron in the sewage. At one plant the sewage usually contains considerable oil and grease. Small amounts of tar are also present at times. During wet weather the sewage from some of the cities

contains fine clay washed into the sewers from the streets. In most places there are still numerous cesspools through which the sewage from the houses flows before entering the sewers. A part of the fæcal matters is thus retained (to be spread on the land) and the sewage becomes septic. The sewage is more or less aërated during its rapid flow in open canals to the disposal works; but on occasions contains appreciable amounts of H_2S (5 to 10 parts in 1 000 000) in solution at the time it enters the clarification plants. Its temperature varies from 50 degrees to 65 degrees fahr., seldom being less than 55 degrees fahr. (even with an air temperature of 15 degrees fahr.) in spite of the fact that the main sewers are uncovered. The minimum temperature of any sewage thus far recorded is 44 degrees, which occurred immediately after a snowstorm. On the whole it may be said that the various sewages now being treated are fully as strong as those from most German cities where the sewage contains very few trades wastes. The per capita flow in the Emscher district is perhaps greater than in other parts of Germany. It varies from 16 to 200 gal. in twenty-four hours. At some of the works the daily and hourly variations in flow are considerable.

At all of the plants the sewage is screened, and in some instances passes through grit chambers before entering the tanks. The screens consist of slanting iron bars laid at an angle of 30 degrees or less with the horizontal, the spaces between the bars being $2\frac{1}{2}$ in. Very little is retained by these screens except large objects such as tin cans, bottles, etc., which would cause trouble in the tanks by clogging the slots (connecting the sedimentation and sludge-decomposing chambers) or the sludge pipe. Grit chambers are used only in cases where the sewage contains considerable sand (from the streets) which would rapidly fill up the sludge chambers in the tanks and interfere with the process of decomposition. The grit chambers are built in duplicate in the form of long, narrow, shallow basins, with their floors 15 to 18 in. below the invert of the sewer. They are so designed that the velocity of the sewage flowing through them in dry weather shall be more than 1 ft. per second. Under these conditions nothing but clean sand is deposited. On the bottoms of the basins are tile drains covered by cinders. Every two or three days, or when the surface of the deposited sand has risen to the level of the inlet, the flow is diverted to the idle basin, most of the water above the sand is drawn off, and the gate at the outlet of the drains opened. The remaining water drains quickly out through the sand, which can then be easily removed





SCREEN AND GRIT CHAMBER } SEWAGE CLARIFICATION PLANT
GRIT CHAMBER } AT ESSEN-FROHNHAUSEN.
SCREEN AND GRIT CHAMBER AT BOCHUM.

with a shovel. It is inodorous and is used as surfacing for the sludge-drying beds. The screens and grit chambers are so built and operated that no putrescible organic matter is retained by them but is carried along in the sewage to the tanks.

Clarification of the Sewage.

The length of time taken by the sewage at the various plants in passing through the sedimentation chamber varies from thirty minutes to $1\frac{1}{2}$ hours. For dry-weather flow it averages about three quarters of an hour. The hourly and daily variations are large; but the removal of total suspended solids from the sewage (through sedimentation) is remarkably uniform, — being from 65 to 75 per cent. Tanks of this type have the advantage that the deposited sludge cannot be disturbed during storm flows by the increased velocity of the sewage passing through them. With horizontal flow tanks the velocity of flow in the sedimentation chambers is usually greater than 5 mm. per second; but less than 1 mm. per second in radial flow tanks. With a weak sewage it was found desirable in one case to keep the velocity (in a radial flow tank) as low as one third of a millimeter per second. With a settling period of three quarters of an hour more than 95 per cent. of the "capable-of-settling" suspended solids are removed. The term "capable-of-settling" refers to the portion of the suspended matters in the sewage which will settle out in a measuring glass when allowed to stand quiescent for two hours.* Three quarters of an hour is not a sufficient settling time if the sewage contains fine coal dust or clay.

Under ordinary conditions no regular scum collects on the surface of the sewage in the sedimentation chamber. Fæcal matters and other organic substances settle to the bottom and pass down into the sludge room. Grease, oil, matches, corks, etc., which collect behind the baffle-board, are skimmed off at intervals of ten days or so and burned. Organic growths which sometimes develop on the inlet and outlet weirs should also be removed.

Although the bottoms of the sedimentation chamber are smooth and slope steeply towards the slots, small amounts of sludge will sometimes stick to them. It therefore becomes desirable to scrape the bottoms clean at intervals of ten days to

---

* See "Operating Control of Sedimentation Plants," by Imhoff, *Engineering Record*, September 3, 1910.

two weeks. The cleaning is easily done with a rubber straight edge fixed to the end of a pole; but there should be no flow of sewage through the tank during the process or for half an hour afterwards so that any sludge particles which have been stirred up will settle again quickly instead of being carried out of the tank in the effluent.

Except for the removal of suspended solids the character of the sewage is practically unchanged as a result of passing through the tank. If the sewage is fresh when it enters the sedimentation chamber the effluent will likewise be fresh; if, on the other hand, H_2S is present in the sewage as it reaches the disposal works, the effluent of the tanks is likely to have a slight odor. It is interesting to note, however, that the quantity of H_2S in the effluent has been found by numerous analyses to be always smaller than in the inflowing sewage. This gas is never found in the effluent if there is none in the sewage as it enters the sedimentation chamber. Theoretically, a small amount of sewage from the sludge-decomposing chamber should rise into the sedimentation chamber for every particle of sludge that passes down through the slots. This consideration has not been found, however, to be of practical importance. It is something like dropping a fish into a pond, — the water level in the pond is not raised very much. It is also true that after the "ripening-time" of the sludge chamber (during which the processes of decomposition are starting up) there appears to be no tendency, even in winter, for the colder sewage flowing through the sedimentation chamber to settle and be replaced by warmer sewage which might come up through the slots from the sludge-decomposing room. The sewage in the lower chamber is permeated with fine suspended matters, and most of the organic matter originally held in solution has been completely decomposed, both of which characteristics may increase its specific gravity. Even in tanks where — from faulty construction or other causes — small amounts of gas from the sludge-decomposing room find their way through the bottoms of the sedimentation chamber into the flowing sewage the effluent of the tanks does not have a noticeable septic odor.

The character of the sewage entering and leaving the tanks at three representative disposal works is shown in the following table.* The determinations are given in parts per million and are

* Taken from "Betriebsergebnisse aus mechanischen Kläranlagen der Emschergenossenschaft" by Dr.-Ing. Spillner and Blunk, *Technisches Gemeindeblatt*, 1911.

averages of the analyses of many samples collected on various days of the week during the six hours that the sewage is strongest. The sewages are alkaline. It will be noticed that the total suspended solids average about 440 parts per million for the three plants. Average figures for the sewages treated at Clinton, Gardner, Hopedale and Worcester, Mass., during the year 1909 are 267, 274, 344 and 400 parts per million, respectively, of total suspended solids.

PARTS PER MILLION.

	Recklinghausen.		Bochum.		Essen, N.W.	
	Sewage.	Effluent.	Sewage.	Effluent.	Sewage.	Effluent.
(1) Total solids...	1387.1	1032.8	2556.7	2031.5	2774.6	2454.2
(2) In suspension	466.6	127.5	402.0	93.3	449.8	135.4
(3) In solution....	920.5	905.3	2154.7	1938.2	2324.8	2318.8
(4) Total organic solids..........	488.9	284.7	435.7	293.8	678.0	417.8
(5) In suspension.	259.3	73.5	186.9	56.4	261.6	85.6
(6) In solution....	229.6	211.2	248.8	237.4	416.4	332.2
(7) Total mineral solids..........	898.2	748.1	2121.0	1737.7	2096.6	2036.4
(8) In suspension.	207.3	54.0	215.1	36.9	188.2	49.8
(9) In solution....	690.9	694.1	1905.9	1700.8	1908.4	1986.6
(10) Total Kjeldahl nitrogen (filtered sample)........	34.4	31.8	28.98	26.04	48.52	44.87
(11) Nitrogen in free ammonia (filtered sample).	23.9	23.3	20.86	18.06	37.66	35.92
(12) Organic nitrogen (filtered sample)........	10.5	8.5	8.12	7.98	10.86	8.95

NOTE:—

(1), (4), (7) and (12) are not actually determined by chemical analysis.
(1) = 2 + 3.
(4) = 5 + 6.
(7) = 8 + 9.
(12) = 10 − [11 + "nitrates and nitrites" (when present)].

TREATMENT OF THE SLUDGE.

The actions taking place in the sludge-decomposing chamber of one of these tanks have already been described in detail in the *Engineering Record* of December 10, 1910. As soon as the tank is placed in operation sludge particles begin to enter the decom-

posing chamber through the slots (*d*) (Figs. 2 to 5). This process is continuous and automatic unless the flow of sewage through the tank is interrupted. The sludge accumulates on the bottom of the decomposing chamber, where, as a result of the decomposition of the organic matter, gas is formed in considerable quantities. Numerous analyses have shown the gases to consist almost entirely of marsh gas (CH_4) and carbon dioxide (CO_2), both of which are practically inodorous. The rising gases exert a stirring action on the sludge which is favorable to rapid and complete decomposition of the putrescible organic matter. Most of them escape into the air at (*f*) (see Figs. 2 to 5); but as a result of the head of water on the sludge many fine bubbles remain imprisoned in it.

No sludge is removed until its surface has risen to a point 18 to 20 in. below the slots, the exact position of the surface being determined at intervals of ten days by means of a flat, weighted board lowered through the openings (*f*) on the end of a string. The time required for the sludge chamber to fill up in this way depends: (1) on the amount of sludge entering through the slots, (2) on the quantity of non-putrescible substance in the sludge, (3) on the rapidity and completeness of the decomposition of the organic matter, and (4) on the size of the chamber. It is spoken of as the " ripening time " because during this period the biological organisms, which play so important a part in the sludge decomposition, are developing and helping to produce the environment most suited to their activities. The decomposition of the sludge is said not to be so rapid or complete during the ripening time as in the second year of operation. With many sewages the time required for complete decomposition of the putrescible organic matter in the sludge is not likely to be much greater than two months. In some of the plants of the Emschergenossenschaft the sludge-decomposing chambers (below the slots) are only large enough so that sludge may accumulate in them during a period of three months before withdrawal; but in the smaller installations where it would be inconvenient to provide for frequent withdrawals the sludge chamber has a storage capacity for twelve to fifteen months.

When the surface of the deposited sludge has risen to the desired point, a small amount is withdrawn from the bottom through the pipe (*c*) simply by opening the valve at the outlet. It is forced out by the head of water in the tank. After withdrawal, the sludge flows in open (or closed) conduits to the sludge-drying beds, or enters a collecting well, from which it is forced through a

pipe to the beds by a low set force pump. It is inadvisable to use a suction pump as the gas bubbles are thereby separated from the sludge. When sludge is being withdrawn from the decomposing chamber some fresh sewage from the sedimentation chamber must of necessity enter through the slots. The amount, however, is comparatively small. The frequency with which sludge is withdrawn from the tanks depends on local conditions and the storage capacity of the decomposing chamber. The intervals between withdrawals may vary from two weeks to six months. Under ordinary circumstances it is better to remove small amounts at frequent intervals, a considerable depth of sludge in the chamber being favorable to decomposition. This is specially important if the portion of the sludge chamber below the slots is not deep. On the other hand, it is sometimes desirable to draw down the sludge level as much as possible at the end of the summer so that it will not be necessary to remove sludge during cold, freezing weather. In no case, however, should all the sludge be withdrawn, because it then becomes necessary for the decomposing chamber to pass once more through the ripening time. Furthermore, the flow of sewage through the sedimentation chamber should not be stopped for long periods because the entrance of fresh sludge into the decomposing chamber is thus interrupted and the processes of decomposition checked. It would also be a mistake to lower the water level in the tank. This relieves the pressure on the deposited sludge and will allow the fine gas bubbles in the decomposed sludge to escape. When the tank is then refilled the sludge becomes packed more firmly together on the bottom. It is not so easy to remove through the pipe nor will it dry so quickly on the sludging-drying beds (as will be explained later). If it becomes necessary to draw out a large part of the sewage for the purpose of making repairs in the tank, most of the thoroughly decomposed sludge on the bottom should first be withdrawn. The upper layers of the sludge deposit may remain, because when the tank is filled again with sewage and placed in operation gases will be developed as a result of the decomposition of the organic matter.

During withdrawal, the sludge should not be allowed to flow out too rapidly through the pipe; because if the well-decomposed sludge on the bottom of the sludge chamber does not move readily towards the outlet, the water pressure from above may force some of the fresher overlying sludge down through the lower layers into the pipe. This can best be prevented by throttling the gate at the outlet of the sludge pipe, and by using the

perforated water pipe on the bottom of the chamber for loosening the sludge just previous to and during withdrawal. Under certain conditions the sludge pipe may become clogged. Troubles of this sort have been experienced when the decomposed sludge has remained for long periods in the tank, and will be likely to happen if small amounts of tar have become mixed with sand in the sludge chamber. The sludge pipe can usually be freed of the clogging material by turning water under pressure into it either from above or from below through the small pipes provided for this purpose, — described under "Design and Construction." After each withdrawal of sludge the sludge pipe must be filled with water (or sewage) from the upper end. If sludge were allowed to remain in the pipe it might become badly clogged. Should the above-mentioned difficulties be experienced where water under pressure is not available, it would always be possible to lower a new pipe into the tank and pump out the sludge.

A few words should now be said about the formation of scum in the upper part of the sludge-decomposing chamber. As a result of the stirring action of the gases developed by the decomposition of the organic matter in the sludge there is always more or less movement in the upper layers of the sludge deposit. If the sludge is particularly sticky or contains much grease and fat the gases will be held fast and masses of the sludge will thereby become so light that they rise to the surface. Much of the sludge which rises in this manner sinks again after the gases have escaped into the atmosphere; but there is usually more or less scum floating on the surface of the sewage in the spaces (f) (Figs. 2 to 5). This scum has no disagreeable odor and as a rule does not accumulate to any great depth. It is loosened up with a rake once a month so that the heavier matters may sink and the gases rising from the sludge chamber may escape easily into the air. Once a year it can be removed with a shovel, if desired, and allowed to dry out on the sludge-drying beds. The movement of the sludge in the decomposing chamber and the formation of scum is usually most noticeable during the ripening time. It may be controlled to a considerable extent by loosening up the sludge on the bottom at regular intervals of ten days or so by turning water into it under pressure through the small pipes for a few minutes. This allows some of the gas to escape and tends to prevent large masses of sludge from floating. The scum which may form if the sludge contains much grease or fat is likely to be particularly light and foamy. It might overflow, on occasion, into the sedimentation chamber unless drawn off through the

outlet (*e*) on to the sludge-drying beds or unless the walls surrounding the spaces (*f*) are extended upwards for some distance above the level of the sewage in the tank. Such conditions may occur once or twice a year and last for a few days, but they can usually be prevented entirely by loosening up the deposited sludge at intervals as already described. Fats and grease in the sludge do not seem to have an unfavorable effect on the rapidity or completeness of the decomposition.

The sludge when drawn out of the tank is similar in some respects to sludge that has been for long periods in ordinary septic tanks. After remaining the necessary time in the decomposing chamber it has changed materially from its original condition. It is a black, semi-liquid, uniform, porous mass having a slight odor of tar or burnt rubber. It is oily in appearance like the soil sometimes found in low swampy land. About one third of the organic matter originally present in the sludge has been converted into gas, the remainder being non-putrescible. The sludge contains on an average only 75 per cent. water, and therefore occupies much less space than when first deposited (in its fresh condition) in the tank. As a result, however, of its gas content and the destruction by decomposition of the fibrous material, it flows easily in channels having a slope of 1:40. Its temperature varies between 55 degrees and 63 degrees fahr., and does not decrease noticeably in cold weather.

The sludge is dried on well underdrained open beds containing 10 to 12 in. of graded slag. The necessary drying time is short, averaging six days in the Emscher district, where there are many rainy days at all seasons. In dry weather it will be spadable at the end of three days. The gas content of the sludge has much to do with the rapidity of drying. When in the tank under 25 to 30 ft. of water pressure the small gas bubbles held fast in the sludge become compressed. Part of them may also go into solution. But as soon as the sludge is drawn out on to the drying beds this pressure is removed. The gases expand, making the sludge porous and light enough to float on the water, which settles out beneath and passes quickly down through the slag into the drains. The gases escape into the air, however, and if the beds are not well drained, the water will rise to the top as the sludge settles again, and a much longer drying period will be found necessary. To prevent clogging of the cinders with sludge particles a layer of fine sand (removed from the grit chambers) is spread on the surface of the beds before each application of sludge. If the weather is very cold or if there is a

heavy rain during the first twenty-four hours of drying, the expansion of the gases (which makes the sludge porous) is interfered with and the drying may take longer than would ordinarily be the case. The volume of the sludge is reduced about 40 per cent. during drying, its water content then being 55 to 60 per cent. The dried sludge is less than 10 per cent. of the volume of the fresh sludge as originally deposited in the tank, and in the Emscher district amounts to about 0.8 cu. ft. per year per person connected with the tanks. As a result of the small volume of the sludge and the rapidity with which it dries, the drying beds may be very small. One square foot of area is ordinarily provided for every three persons, and it has been found that one man (the caretaker of the disposal works) can handle the sludge from 30 000 people if the point of deposit is in the immediate vicinity of the plant. Six cubic meters of sludge have been dried on one square meter of sludge-drying bed in a year. The water which drains out of the sludge on the beds is sometimes turbid, but otherwise unobjectionable, and entirely free from odor. It contains only small amounts of nitrogenous organic matter, is high in nitrates and non-putrescible.

At most of the plants operated by the Emschergenossenschaft the sludge is used for filling in low areas, being shoveled from the drying beds into small cars on rails and pushed by hand to the dump. It should not be removed from the beds till thoroughly dried. Otherwise it may remain soft (though unobjectionable) for long periods. The dried sludge is firm, porous and free from disagreeable odor even during warm, muggy weather. It looks much like garden loam, can be piled in deep layers and supports vegetation. The sludge when removed from the drying beds is so unobjectionable that the wives of the peasants who buy it for fertilizer help to load the wagons.

DISCUSSION.

Mr. George W. Fuller (*by letter*). — The writer regrets that he is unable to attend this meeting and listen to Mr. Saville's description of what the writer regards to be the most important advance taken during the past five years in the art of sewage disposal.

A combination two-story sedimentation and septicization tank is unquestionably superior to the old single-story tank in which both processes take place in the same compartment. It

assures a fresh or substantially fresh clarified sewage for application to filters or for dispersion into streams of sufficient size. It avoids the necessity of dealing in the effluent, at least at times, with objectionable suspended matter lifted by gas bubbles from the sludge at the bottom of the tanks. It also eliminates the awkwardness, in cleaning tanks from time to time, of disposing of liquid and solid matters of an organic nature which have not been rotted to an extent to insure substantial freedom from odors.

The latter point stands conspicuously in the mind of the writer because with many fresh sewages, particularly if unscreened, gas ebullition in the old single-story septic tank carries suspended matters to or above the flow line, and envelopes them in gas so that bacterial decomposition does not take place until these solids are deposited in sludge beds, where odors may arise. The slotted partition of the Travis and Imhoff tanks, by promoting the simple and automatic removal to the digestion chamber of the sludge as it forms, is a decided improvement, as compared with the single-story tanks.

The separate digestion of sludge in compartments having substantially no connection with the sedimentation is, of course, not wholly new with the Imhoff tank, as it was studied at Lawrence some ten years ago or more and was recommended by Mr. Hazen in the project designed for Paterson, N. J., four or five years ago. At first the writer was inclined not to consider it necessary, but for reasons above stated he is now in favor of separate sludge digestion on the ground that it frequently is very advantageous and in no instance is it likely to be disadvantageous.

On the general question of odor production in tanks of the Imhoff type, there seems to come from the Emscher district comparatively little of a scientific nature that makes our understanding of the septic process any more clear than it was some four or five years ago, when the scientific premises were outlined in the Baltimore report by Messrs. Hering, Stearns and Gray, in May, 1906.

There is nothing to indicate that the Emscher tank promotes any especially favorable growths of bacteria that would not occur in a plain septic tank. Sulphureted hydrogen is doubtless formed from the hydrolysis of organic matter in the Emscher tanks as well as in all other septic tanks. There are no novel features that the writer knows of in relation to sulphureted hydrogen that are touched upon in any of the evidence from the

Emscher district. Reference is here made in particular to the true sulphur bacteria which, of course, do not produce sulphureted hydrogen, but, on the contrary, live upon sulphureted hydrogen and convert it to metallic sulphur.

Another group of bacteria which might be spoken of are the sulphate-reducing bacteria which are capable of producing sulphureted hydrogen by the reduction of the mineral sulphates. The latter seem to be a factor of importance in southern California (Los Angeles and vicinity) and a number of other places (Nuneaton, England), where the writer has observed unusual quantities of sulphureted hydrogen.

Information is needed to indicate whether the tanks in the Emscher district are aided by the growths within the digestion chamber of bacteria which consume sulphureted hydrogen or whether, on the other hand, they are handicapped to any appreciable extent, if at all, by the sulphate-reducing bacteria which have proved so bothersome at a few places elsewhere.

In connection with the general proposition of odors from sewage decomposition, it is necessary to bear in mind that there are other compounds than sulphureted hydrogen. Among them may be mentioned indol, skatol, mercaptan, etc. Whether any of these are important factors in odor production in the works in the Emscher district or elsewhere is something upon which more light is needed.

Speaking generally of the question of odor production, it appears to be generally considered that sulphureted hydrogen is the main factor to be kept under control. Here it is desired to point out that this gas is quite soluble in water; in fact, one volume of water will hold from three to four volumes of sulphureted hydrogen gas, depending upon temperature and pressure. It so happens, however, that sulphureted hydrogen generally finds in sewage some substances of a chemical nature with which to combine, notably iron salts, which form precipitates such as ferrous sulphide. It is necessary, therefore, to consider that sulphureted hydrogen in water, in order to rise into the atmosphere and produce troublesome odors, must be produced in quantities sufficient to combine chemically with iron and other salts in the tank and also to supersaturate the liquid in the tank. It will be interesting to know to what extent sulphureted hydrogen in the digestion chamber of the Emscher tank is precipitated.

The escape of sulphureted hydrogen probably occurs very rarely in ordinary septic tanks. In fact, in so far as the writer

knows, no analyses indicate that sulphureted hydrogen has ever been found in the collected gases in septic tanks. There is no doubt, on the other hand, that sulphureted hydrogen does escape into the atmosphere at some places on some occasions. This is probably due, in the opinion of the writer, to some concentration of substances within the tank which produce an amount of sulphureted hydrogen sufficient to supersaturate a limited quantity of the overlying liquid after the precipitating effect of iron and other salts has been brought about.

If the thought above expressed is correct, it is probable that the Imhoff tank has advantages in bringing about a stirring action within the digestion chamber which proves most helpful in allowing sulphureted hydrogen to be dispersed through a considerable volume of liquid. This may be accomplished, of course, in part by the stirring due to ebullition of gas and in part by stirring which may be accomplished, if need be, by the application of water under pressure through suitably perforated pipes. The stirring effect by gas or water probably has much to do in explaining the substantial liquefaction of sludge by preventing the so-called toxins from interfering seriously with hydrolysis as effected by enzymes. This probaby means nothing more or less than that the acids resulting from hydrolysis are diffused so as not to bring about any interruption in the action of the enzymes through their own by-products.

It will be interesting to know to what extent the character of the sludge as removed from the digestion chamber is due to coagulating effect of salts of iron.

The Chairman. — Mr. Gage, could you give us an account of the work done at Lawrence? If I remember correctly, Mr. Clark read a paper in 1899 before the American Public Health Association in which he described this treatment, — that is, separation of the sewage and sludge in different tanks.

Mr. Stephen DeM. Gage. — Mr. Weston's memory is not at fault in his reference to Mr. Clark's paper before the American Public Health Association. This paper was read at the Minneapolis meeting on October 31, 1899, and in it Mr. Clark stated, "I believe a modification of the septic tank could be constructed, intended to treat only the matters in suspension in the sewage and settled out daily while passing through ordinary settling tanks, flushing this accumulated sludge when necessary into a septic tank." The origin of this idea is thus stated by Mr. Clark on page 422 of the report of the Massachusetts State Board of Health for the year 1899. "The observation that the

stronger the sewage entering a septic tank the greater is the removal of organic matter suggests the idea that, where exceedingly large volumes of sewage are to be purified, as in the case of the sewage of a large city, this sewage could be passed through ordinary settling tanks, so constructed that the sludge settling to the bottom of these tanks could be flushed into a septic tank and this sludge alone be treated by septic action, instead of attempting to treat the whole of a city's sewage. Following up this idea, a septic tank was put in operation during November, 1899, to receive the strong sludge from settled sewage." This tank was a double-deck affair, with a settling tank on top and a septic tank for the sludge below. Sewage was allowed to settle for four hours in the upper tank, the supernatant 90 per cent. was then drawn off and the remaining 10 per cent. containing the settleable sludge was allowed to flow into one end of the lower tank, an equal volume of liquid being displaced through an outlet at the opposite end. The heavy sewage entering the sludge tank contained on an average about 14 300 pounds of suspended matter per million gallons, or about seven times as much as the regular Lawrence sewage. The volume of this concentrated sewage entering the sludge tank daily was about one fifth of its capacity during the greater portion of the time. About 82 per cent. of the suspended matters entering the sludge tank were deposited, and about three fourths of the matters so deposited were destroyed within the tank. The dried sludge from this tank after about one year of operation contained about 46 per cent. of mineral matter and about 54 per cent. of organic matter. After about two years of operation, the amount of sludge held in the tank had accumulated to such an extent that it was difficult to keep it in operation, and it was evident that the capacity of the sludge tank was too small to care for the amount of suspended matters which were entering it. The daily admission of sludge into the tank was therefore stopped and the tank with its contents was allowed to stand quiescent for a period of four months, during which time the volume of sludge in the tank decreased more than one half. A second tank of this type was operated at Lawrence from 1904 to 1907, but the concentrated sewage entering the sludge tank did not contain such a large proportion of suspended matters as in the earlier experiments. The results with this tank were very similar to those obtained with the earlier tank, so far as deposition and destruction of sludge were concerned, but as the tank was of much larger capacity in proportion to the amounts of suspended matters entering daily, clogging did not occur.

Another septic or "hydrolytic" tank, started at Lawrence in November, 1899, was an upward-flow tank completely filled with broken stones, with the idea of providing a largely increased surface for the deposition of sludge. I mention this here, because it was from the reports of the operation of these two early Lawrence tanks that Dr. Travis drew his ideas which he combined and developed into the well-known Travis or Hampton tank. While Dr. Travis has freely and fully acknowledged the source of his inspiration, this fact has been entirely overlooked by the majority of American writers on the subject of sewage disposal.

In the early days of the septic tank we made many experiments to find out something about the destruction of sludge by biological action. One of these, made in 1898, may illustrate the changes taking place in the sludge in the Imhoff tank. Two glass tubes about 5 ft. long and 2 in. in diameter were completely filled with heavy sludge. One of these tubes was sealed and the other was left open, and both were placed on end in the laboratory where the action within them could be watched. At first the sludge settled to the bottom, leaving a layer of clear supernatant liquid at the top. After a day or two, evolution of gas commenced, and much movement of the sludge occurred. This continued for about six weeks, and then stopped. Bacterial analyses of the sludge at this time showed the almost entire absence of the ordinary types of sewage bacteria. Later, however, bacterial life again became active and an abundant growth of pleurococcus developed, and the volume occupied by the suspended matters became gradually less and less. After about eight months the sludge had shrunk to about half of its original volume and had become practically odorless, and little or no further action was observed.

In 1904, some experiments were made at Lawrence to test the destruction of paper and cotton and woolen cloth in a septic tank, and it was found that the vegetable fibers were completely destroyed in about eight months or less, but that the animal fibers required about twice as long.

Recently we have had in operation at Lawrence a tank similar to one of those Mr. Saville has illustrated, except, of course, on a very much smaller scale. This tank has a sludge or digestion chamber with a conical bottom, inside of which is suspended a smaller settling tank, also with a conical bottom, with an opening at the bottom so arranged that the sludge will flow into the digestion chamber but any floating matters cannot get back into the settling tank. For the past eighteen months,

we have been passing the fresh sewage from our station water-closet through this tank. About 53 per cent. of the suspended matter has been removed from the sewage in its passage through the tank. From a sludge standpoint, the operation of this tank has not been particularly successful. At the present time over 70 per cent. of the capacity of the digestion chamber is filled with sludge and floating matter, although sludge has been removed from time to time to prevent it from backing up into the settling chamber. In spite of the fact that some fermentation is going on in the tank as shown by evolution of gas and the presence of a crust of floating matter, the sum of the total amount of solids in the tank at the present time and of the solids in the sludge which has been withdrawn from the tank, approximates very closely the total amount of suspended matters removed from the sewage in its passage through the tank. In other words, there has been little or no hydrolysis of the sludge in the tank. The sludge as drawn from the bottom of this tank contains about 87 per cent. of water, has a consistency of thick pea soup, is light yellow in color, and of an extremely offensive odor. This odor is not that of hydrogen sulphide, but is distinct and penetrating, more like that of fresh dysentery stools. On placing this sludge in a jar, it retains its identity for days, and the solids and water do not separate. The failure of this tank to yield satisfactory results may be attributed in part at least to the nature of the entering sewage, and in part perhaps to the fact that the depth of the digestion chamber is only about 5 ft. instead of the 25 or 30 ft. which Mr. Saville states to be essential.

While listening to that part of Mr. Saville's very interesting paper in which he describes the condition of the sludge drawn from the Imhoff tank, and the ease with which the water may be separated from it by draining on sludge beds, leaving it in a porous, spadable condition, as he calls it, it occurred to me that perhaps a mistake has been made in the operation of septic tanks at times. We are all familiar with the fact that a thick crust of sludge forms on the surface of many septic tanks. Septic tank sludge is generally offensive, slimy and difficult to dispose of, but this crust is porous and could probably be handled and disposed of with much less difficulty. So far as I know, the practice has always been to allow the crust to remain, and to draw sludge from the bottom of the tank when necessary, but perhaps a reversal of this procedure and the removal and disposal of the floating matters might be an improvement. Mr. Saville stated that the removal of floating matters from the

Imhoff tank is provided for, and is practiced at times, and it would seem that this practice might also be applied to the septic tank.

Mr. Harrison P. Eddy. — I think one of the interesting features of this paper is that relating to the practice which seems to have been adopted in the Essen district of keeping the sewage as fresh as possible. This is another instance of the growing tendency in that direction and is substantial confirmation of the theory held by a number of sewerage engineers that it is a mistake to allow putrefaction where it can be avoided and that it should only in rare cases be encouraged.

I have been particularly interested in the disposal of the effluents from these tanks into the open drains, and I think it would be enlightening if Mr. Saville would tell us something about the natural flow of the streams — whether they are so small that there is nothing but sewage in them, or whether there is some water to assist in holding them in a fresh condition, with a supply of oxygen, sufficient to prevent putrefaction. Of course, the rapidity of flow, which has been described, assists materially in maintaining such a condition of equilibrium. It would also be of interest to learn about the summer temperatures, both of air and the water flowing in the streams. Are these temperatures substantially the same as in New England where we are familiar with local conditions and the effect of dilution of sewage with the waters of our streams?

It seems very evident from Mr. Saville's discussion, as well as from current literature upon this subject, that Dr. Imhoff has succeeded admirably in designing a tank which effectually separates two of the desirable functions of the settling tanks; namely, the deposition of suspended solids and the concentration and fermentation of the sludge, thereby reducing its volume but without injuriously affecting the character of the sewage during its passage through the basin. On the other hand, however perfect the details of construction may be, the speaker is of the opinion that success or failure of this apparatus must depend upon the method of operation, by which is meant the care with which the fermentation of the sludge is watched and the period of storage regulated. As has been clearly pointed out by Mr. Saville, it is possible to allow the sludge to accumulate to such an extent that the lower chamber does not perform its function as it should. It is quite conceivable that under conditions such as have not infrequently been found to exist in this country, this tank might fail in producing the result for which it is built because of in-

efficient operation by municipal employees who lack both interest in and knowledge of the principles involved. The operation of this tank should be a simple matter for one who understands clearly the action going on within it, and there is no apparent reason why an intelligent workman cannot be so instructed that he will be perfectly competent to operate it.

One good feature in the design of the tank is the small area of the sewage in the sludge compartment which is exposed to the air. With due respect for Mr. Saville's observations, which indicate that there is very little offensive odor even close to the surface of the liquid in sludge reservoirs, it can hardly be hoped that some cases will not arise in which offensive gases will be generated. In such cases the small area of liquid exposed will give this type of tank a distinct advantage over the old shallow, horizontal, tanks in which the area of sewage exposed to the air is very much larger.

It is also probable that the action of this tank will vary materially with the temperature and the character of sewage. Where the sewage is cold, the fermentation will undoubtedly go on at a much slower rate than where it is warm, and this would naturally require a longer period of storage in the tank.

In a similar manner putrefaction may be retarded by chemicals such as pickling liquids, or tannery wastes. It would seem, however, that the construction of the tank is well adapted to the fermentation of sludge deposited from such sewage, because of the fact that the quantity of the sewage containing spent chemicals, which is in contact with the sludge, is comparatively small. When the tank is first started the lower compartment is filled with sewage and the retarding action due to the chemicals may be effective for a considerable period of time. This, however, will be overcome by the gradual development of bacterial life in the sludge, and after the fermentation becomes active it is improbable that the character of the sewage will interfere materially with this action because the quantity admitted to the fermentation chamber will be so very small in comparison with the quantity of sludge discharged into it. If this theory is sound, it would seem to point to a decided advantage in this type of construction for sewage containing chemicals.

While it is undoubtedly true that the sludge, filled as it is with gas when discharged from the tank, dries with considerable rapidity upon thoroughly underdrained and well-prepared beds, we should not lose sight of the fact that sludge from ordinary sedimentation tanks, when discharged upon similar beds, can be

dried without great delay. Judging from the description of the drying of the sludge from the Emscher tank as given by Mr. Saville, who is well acquainted with the drying of sludge from ordinary sedimentation tanks, there appears to be a decided advantage in favor of the new tank. It is a fact, however, that in this country sludge drying beds have only in rare cases been so constructed as to facilitate the very rapid draining of the sludge.

Mr. Saville. — Perhaps I can tell Mr. Eddy a little bit about what he wants to know. Many of the smaller streams and tributaries of the Emscher River which receive the discharge from the sewage clarification plants contain practically nothing but the sewage that comes into them. In other words, the dilution is practically *nil*. And in such cases there is no nuisance, because the velocity is rapid and the sewage, after once being clarified, flows away quickly. Everything is, however, in a period of transition at the present time. Only eight of the clarification plants are completed and only part of the streams are regulated. Five years from now, when everything is finished, will be the time when we shall be in a position to say whether this method of disposal is satisfactory for the existing conditions. The question of temperatures is, of course, important. In the Essen district they do not have, so far as I know, any extremely hot weather, such as we have here. Their annual rainfall is 30 in., which is less than ours. It is distributed very uniformly throughout the year and the variations in flow in the streams are perhaps not so great as with us in America. The Emscher River at the present time is in a bad condition, because much unclarified sewage is still being discharged into it, and the complete regulation of the channel as planned has not yet been carried out. It is therefore not possible to say how successful the general scheme will prove to be. The flow of the river during dry weather is about 66 000 gal. per square mile of watershed per day. A large portion of it is mine drainage, which has been treated in settling tanks for the removal of the fine coal dust. The remainder consists of sewage, and ground water. It will certainly be interesting to see, when all the works are completed, whether the combination of good grades, smooth channels and rapid velocities will be effective in preventing a nuisance when most of the sewage receives no treatment other than clarification.

It is a fact that, although the sewage at the upper end of an open sewer may be septic and rather odorous, flowing for a mile or a mile and a half with a good velocity improves its character

very much. Many of the engineers in Germany believe that it is perfectly possible to keep sewage fresh and to improve its character simply by providing proper conditions of flow. It is well known that at Wiesbaden and other places they spend money and take pride in building their sewerage systems as perfect as possible — with smooth surfaces and good grades — so that there is no chance for deposits to occur. Furthermore they flush their sewers twice a week, sometimes oftener, and sections of the system are lighted by electircity, so that by paying twenty-five cents it is possible to go through them in a boat and see everything. Perhaps more money is spent in Germany than in other countries for the purpose of keeping sewage fresh until it gets to the point of disposal.

Prof. Earle B. Phelps. — I am quite sure Mr. Saville has given us all a great deal to think about this evening. I am particularly impressed with his very conservative attitude toward this tank, for it has seemed to me for some time past that it was unwise to pin our faith too strongly to any such new device in the absence of more thorough data under conditions of American practice. We all recall the enthusiasm that was aroused in the early days of the septic tank. Very great things were claimed for it and those who knew it best had no hesitation in claiming that it was a complete solution of the sludge problem. The fact is, sewage is a very diverse product. In our present ignorance of the fundamental chemical and biological changes that underlie sewage treatment, one hesitates to make or accept any very broad generalizations. We have seen so many unaccountable things in the case of the septic tank that I should not be at all surprised if similar interesting experiences were in store for us along these newer lines. Septic tanks as nearly alike as possible in design and operation, and treating sewages that so far as can be determined are pracitcally identical, have given very diverse results. Some tanks have gone for years without cleaning and without serious accumulation; others, notably that at Plainfield, New Jersey, have at times required cleaning at very frequent intervals to prevent a complete clogging of the entire tank. Even in the matter of odors, septic tanks have differed markedly among themselves, and I anticipate that in this respect the Imhoff tank may not always act the same. Reference has been made, this evening, to the production of hydrogen sulphide in septic tanks. If Mr. Fuller could have seen some of the septic tanks that we operated for several years upon Boston sewage, he would have a somewhat different opinion upon the production

of this gas by septic action. The odors were not only distinctly noticeable, but within a confined space were almost sickening at times. In this case, we know perfectly well that the sulphur comes from the sea-water contained in the Boston sewage. Similar experiences were had at Worcester, due to the sulphate of iron present, and can be noticed by any one at the Columbus works where the sulphate occurs normally in the city water. I have no reason to believe that the Imhoff tank or any other tank, favoring anaërobic fermentation would not under similar conditions give the same result. Therefore, in this respect in particular, we must be conservative and not place tanks of this character in too close proximity to beautiful dwellings as shown in some of Mr. Saville's slides. It is plainly evident that, in these Imhoff tanks, German investigators have a solution for their own local problem which far surpasses anything that has been developed in American or English practice, and we shall all await with interest the application of this principle to American conditions. The general proposition to maintain the freshness of sewage as far as possible before treatment upon filters is one with which I am in hearty accord. About the time that the Columbus experiments were under way, Professor Winslow and I concluded, as the result of our experiments upon Boston sewage, that septic tanks for large cities were not only unnecessary but were distinctly disadvantageous. In the light of the Columbus experience, up to this time, my confidence in this position is redoubled. I am more firmly convinced than ever that cities of the size of Boston, Baltimore, and even Columbus require no septic tanks or even preliminary sedimentation to fit their sewage for application to sprinkling filters. We have demonstrated satisfactorily through a six years' continuous experiment that the crude sewage of Boston can be run upon trickling filters without other preliminary treatment than is given by a short period in a grit chamber and by screening through half-inch screens. With the introduction and development of fine-mesh mechanical screens, it is my belief that except in the case of comparatively small communities tanks of all kinds may be dispensed with to great advantage, both in the question of odors about the works and of efficiency of the filters themselves.

MR. LANGDON PEARSE (*by letter*).—The writer wishes to add to the discussion a few notes taken from his observations on an experimental Emscher tank which is running on a weak American sewage. The tank is part of the Sewage Testing Station of the Sanitary District of Chicago, of which the writer has

charge, and has been in operation since May 26, 1910. The tank is built of wood and is approximately 7 ft. 6 in. inside diameter, and 16 ft. 11 in. working depth. The arrangement of the baffles and sludge chamber is shown in the drawing. The results so far have shown that the effluent from a grit chamber containing on an average from 100 to 200 parts per million of suspended matter, as determined by the Gooch Crucible Method, requires at least two hours' period for settling, with an average vertical velocity of less than $3\frac{1}{2}$ ft. per hour. The average removal during the month on the two-hour period has been as high as 55 per cent. reduction of suspended matter with 152 parts per million in the influent, and on occasional two-day tests a reduction of 65 per cent. has been obtained, with the suspended matter in the neighborhood of 200 parts per million. The average rate of accumulation of sludge with the two-hour period has been about 2 cu. yd. per million gallons, with a water content of about 90 per cent. The intention is to lengthen the period of settling. The treatment of the sludge as yet has not been taken up as the tank apparently was just ripening as freezing weather set in. In our experimental tank, the capacity of the sludge chamber is estimated at one year. It is not probable that this storage will be required in an actual plant, but the minimum storage required in cold climates would seem to be fixed by the length of time required to tide over the winter months, as in the cold climates there are from four to five months in the year during which the sludge cannot be handled out of doors to any advantage. The conclusions of the writer have been that from the standpoint of mechanical construction, ease in cleaning, freshness of effluent, lack of hydrogen sulphide odor, and the treatment of the sludge, the Emscher tank seems the most desirable of the present methods for preparatory treatment.

Mr. George W. Fuller in his discussion has called attention to the fact that the separate digestion of sludge is not new. From observations made of the sludge tank at the Sewage Testing Station in Chicago, the writer would like to emphasize the fact that the separate digestion of the sludge in separate tanks is in itself not a solution of the sludge problem, and if carried out on any large scale may prove a great nuisance. The success of the Emscher tank, to the writer's mind, lies in having a separate compartment for the digestion of sludge, to which the increment of freshly settled suspended matter is coming every moment. If the sludge accumulation of a sedimentation basin is blown out into a sludge digestion tank whenever septic action begins to

develop, or even at more frequent intervals, a large mass of partially digested sludge is thoroughly stirred up. Violent gas production will ensue in warm weather, with the consequent dissemination of the settled matter through the liquid. In Chicago a noticeable putrid smell was produced, which proved to be the only nuisance in the entire Sewage Experimental Station. It is quite evident from our experiments that the action is different in the sludge chamber of the Emscher tank, and in the sludge digesting tank as an appurtenance to a settling basin. The question also comes up of handling the excess supernatant liquid from sludge digesting tanks. If it is pumped over into the sedimentation tank, as it should be for treatment in the sprinkling filters, it would certainly tend to start septic action. In the summer it is so foul that it cannot be discharged without treatment.

Investigations are now being made on the problem of the production of odor from various types of tanks, particularly from the Emscher tank and a modified Dortmund tank. The modified Dortmund tank which we are operating at Chicago is similar in design to the one installed at the Calf Pasture Testing Station of the Massachusetts Institute of Technology. It has been running for over six months, producing a large amount of hydrogen sulphide through the warm months, the production of gas persisting even in cold weather. The odor is particularly noticeable in the orifice boxes and on the sprinkling filter, to which the effluent is applied.

The question of dissemination of odor is a very interesting one. The writer does not wholly agree with Mr. Fuller's explanation of what does occur. The laboratory results do not show that the liquid is by any means saturated with hydrogen sulphide. It is possible that a thin surface layer may become saturated, and so transfer the odor to the neighboring atmosphere. Where the gas is evolved in bubbles, it seems to the writer very probable that the size of the bubbles should have something to do with the difficulty of going into solution. The larger the bubbles, the less the tendency to dissolve. The depth of the tank also will have some effect. It is probable that the advantage of the Emscher tank in restraining odors is partly mechanical, in that the sludge chamber is far deeper than the single deck septic tank. The bubbles formed must attain a greater internal pressure in order to be released in the greater depth. There is consequently a longer travel and probably a greater tendency to go into solution, as well as a delay in the setting free of the gas. The question of odor from a tank opens

up the question as to how it is possible to smell any liquid that contains odoriferous liquid or solid. The writer would suggest that possibly some chemical physicist can answer this question through the solution tension of the gas or solid, as it would seem offhand that most liquids containing any gas or solid can be smelled at a point below the saturation point.

Dr. Arthur Lederer * (*by letter*). — In the discussion of this paper, the writer has been particularly interested in what Mr. Fuller had to say about the presence of hydrogen sulphide in the septic tanks and the Emscher settling tank. There has never been a hydrogen sulphide odor noted in the effluent of any of the septic tanks at the Sewage Testing Station of the Sanitary District, not even during the hot season, when the evolution of gas was at its highest. The writer has occasionally tried to obtain a qualitative reaction for hydrogen sulphide in the effluents. At times there was an indication as to hydrogen sulphide being present in very small quantities. These observations hold true also for the effluent of the Emscher tank. However, this may not mean that the tanks are entirely devoid of hydrogen sulphide in all parts. The supernatant liquid of the sludge digesting chamber of the Emscher tank, while giving no hydrogen sulphide odor, gave a positive reaction for hydrogen sulphide.

Since the process in the septic tanks is a strong reduction process, it is only fair to assume that the organic and inorganic sulphur compounds likewise become reduced, thereby forming hydrogen sulphide. This does not hold true to the same extent as it does with the nitrogenous constituents for various reasons, chief among them is that the sulphur compounds in the sewage are not apt to yield as quickly to hydrolytic changes. A large part of the sewage bacteria form hydrogen sulphide in a special medium containing sodium thiosulphate; likewise there must be species of bacteria which reduce the sulphates. We find, for instance, in our case, that a crude sewage with a content of 23 p.p.m. sulphur in the form of mineral sulphates will show but 1.3 p.p.m. of sulphur as sulphates in the effluent of our Dortmund tank, which smells strongly of hydrogen sulphide gas. The difference in the sulphur content is accounted for in the presence of hydrogen sulphide, sulphides, and free sulphur. The study of these bacteria would seem of great interest. Of course the iron in the sewage is entirely taken up by the hydrogen sulphide, so we find in our case that the 2.1 p.p.m. iron in the crude sewage is reduced to but a trace in the effluent of the Dortmund tank.

* Chemist, the Sanitary District of Chicago.

In connection with the large reduction of mineral sulphates in this tank, it is also interesting that the sprinkling filter which receives the effluent is covered with a growth of beggiatoa, which oxidized the sulphide so that the sprinkling filter effluent shows 7.6 p.p.m. sulphur in the form of sulphates. It is the writer's opinion that provided the mineral iron in the crude sewage sample is not thrown out of solution on standing for a few hours, then the decrease of soluble iron in passing through the tank may be taken as a fair measure of the hydrogen sulphide evolved.

It does not take a great deal of hydrogen sulphide to cause a perceptible odor. Rough laboratory tests have shown that about 2 p.p.m. in solution free from other odors can be easily detected. The hydrogen sulphide may be present, however, without causing an odor, as is the case in the supernatant fluid of the digestion chamber in the Emscher tank. Under outdoor conditions and in the presence of other putrefactive odors, an amount of 2 or 3 p.p.m. hydrogen sulphide in the tank would not be noticeable.

MR. A. B. MORRILL * (*by letter*). — In the discussion of Mr. Saville's paper the question of the production of hydrogen sulphide odor in sewage tanks has arisen. Mr. Fuller states that "sulphureted hydrogen in water, in order to rise into the atmosphere and produce troublesome odors, must be produced in quantities sufficient to combine chemically with iron and other salts in the tank and also to supersaturate the liquid in the tank," and he also says that "one volume of water will hold three or four volumes of sulphureted hydrogen gas, depending on temperature and pressure."

Water at 10 degrees cent. and at atmospheric pressure will dissolve 3.7 volumes of hydrogen sulphide. But if the space over the water is occupied by a mixture of gases the solubility of the hydrogen sulphide is determined, not by the total pressure on the liquid, but by the partial pressure of the hydrogen sulphide; that is, the pressure which the hydrogen sulphide would cause if it alone occupied the space.† In order to dissolve 3.7 volumes at atmospheric pressure, water must be overlaid by an atmosphere of hydrogen sulphide.

As our atmosphere is practically unlimited and free from hydrogen sulphide it is evident that any solution of hydrogen sulphide, however dilute, is supersaturated and unstable when

*Engineering Assistant, the Sanitary District of Chicago, 39th St. Sewage Testing Station.

† Mendeleef, "The Principles of Chemistry," Vol. I, p. 82, 1905.—*Ed.*

exposed to the air. Mendeleef says, "Water saturated with a gas which is not contained in air will be entirely deprived of the dissolved gas if left exposed to the air." *

This demonstrates the fact, which is borne out by experiment, that solutions of hydrogen sulphide give off the gas and may produce odors when they are far below the saturation point. Experience in the laboratory shows that such solutions have a distinct odor when they are less than 1 per cent. saturated. The same phenomenon is noticed with ammonia, which is extremely soluble in water. The solutions used for laboratory and domestic purposes are far from saturation and still give off a strong odor.

The escape of hydrogen sulphide from tanks may occur even though the tank contains an excess of iron salts in solution. In a shallow tank large bubbles might form in the sludge, rise, and escape into the air without going into solution or having an opportunity to combine with the iron.

The depth of the Emscher tank tends to prevent the escape of hydrogen sulphide when the sludge chamber contains salts which would precipitate it from solution, and the scum which is generally present at the surface of the sludge chamber retards its diffusion into the atmosphere. The absence of odor near a tank indicates, however, that there is little or no hydrogen sulphide produced above the amount necessary to combine with the iron and other metals in solution.

Mr. George W. Fuller (*by letter*). — The discussions by Messrs. Pearse, Lederer and Morrill of the Sewage Testing Station of the Chicago Sanitary District contain a number of interesting and valuable points, and the writer is glad of the opportunity to comment briefly on several of them as follows:

Separate Sludge Digestion Tanks.

While the writer does not take exception to Mr. Pearse's statement that the Emscher tank for large works seems the most desirable of the methods now available, it is believed that he is rather drastic in saying that the digestion of sludge in separate tanks is in itself not a solution of the sludge problem. Last autumn there was put in service at Kings Park, N. Y., a sewage purification plant for treating the sewage of a population of between 3 000 and 4 000 people. The preliminary treatment consists of plain sedimentation in tanks of the Dortmund type.

* Mendeleef, Vol. I, p. 86, Note 36.

From the bottom of the tanks the unputrefied sludge is removed at intervals by opening a gate on the outlet pipe, through which the fresh sludge by the weight of the superincumbent sewage is forced to long covered sludge trenches. These trenches are about 6 ft. deep and 6 ft. wide, braced on the sides and top with rough lumber and covered with a foot or more of sandy soil. The sludge is distributed lengthwise in these trenches by means of a trough, so that it can be deposited at different points by adjustments made through openings which are ordinarily covered. There is an overflow pipe to take the liquid, if necessary, when the trench is filled, to a pipe leading to the final settling basin into which the effluent from the sprinkling filters passes. Such liquid as does not percolate into the porous soil may be treated with hypochlorite of lime as it flows into the final settling basin.

The only feature suggesting modification in the preliminary treatment at the Kings Park plant is the formation of scum on the surface of the clarified sewage in the Dortmund tanks. This is largely due to the fresh and but partially screened sewage entering the Dortmund tank and probably would also appear in an Emscher tank. The sewage seems to be unusually well clarified at the Kings Park plant and is delivered to the sprinkling filters in a fresh condition. The covered sludge trenches, it is believed, will afford a disposal of the sludge without odors at a very small or moderate cost for construction and at practically no expense for operation for several years. The opening of a valve now and then is all that is required of the attendant, who need visit the plant only for a few minutes once or twice a day. Ultimately, it will be necessary either to dig out the sludge from the existing trenches, or to build new ones. The writer is by no means certain that with either or both of these operations the separate covered sludge trench, or basin, is not cheaper for a plant of this size for some locations than is an Emscher tank, with its sludge beds which are supposed to need attention at such frequent intervals as to require the regular employment of a laborer.

Just how much attention is needed for an Emscher tank in our northern climate, especially as to the frequency with which the sludge is to be removed, is a question of considerable practical significance. It would seem to be a difficult matter to remove and dry sludge without complications from freezing for quite a number of months at a time at many places. This affects construction costs in some measure if ample storage of sludge in the digestion chamber is to be provided to tide over winter weather and a period in the spring sufficient to allow the

sludge accumulations of the winter to become well rotted out. It also affects the maintenance cost if during the summer months it means a regular attendant to operate a sludge-drying bed at frequent intervals. It is quite easy to get an attendant on to the regular payroll in some places and the capitalization of this annual cost has considerable significance with the comparisons of the Emscher tanks which the writer has mentioned above, with small designs of the Kings Park type where no regular laborer need be employed, but where special labor may be provided at intervals of once or twice a year.

An interesting point in connection with the removal of sludge from Emscher tanks on to drying beds is whether or not entrained gas remains in the bottom sludge for an indefinite period and to a sufficient extent to permit the sludge to rise through the water in which it is contained, and thus afford an opportunity for prompt drying which seems to be so characteristic of the sludge of the Emscher tank when working at its best.

It is reasonable to suppose that the Emscher tank can be built rather more cheaply than some of the present designs would indicate. Comparison of the construction cost of the two-story Emscher tank, having a septicization chamber of ample size and also a sludge-drying bed, with the cost of a Dortmund tank to give equal clarification and provided with covered trenches, indicates that where sufficient porous land is available the arrangement built at Kings Park would not be the more expensive even if sludge trenches were provided initially to take care of the sludge for quite a number of years without removal. The question then becomes for small plants one of comparison of the cost of operation and maintenance of the two types. Whatever advantage may result from the Kings Park design is predicated upon the necessity of the attendant's spending only a few minutes a day with such a plant, whereas it might be a question of several hours a day or continuous employment for a laborer during the warm season of the year with the Emscher arrangement.

It is not to be forgotten that for some localities it might be wise to dispose of the sludge from Emscher tanks into covered trenches or basins, if for no other reason than to keep the material hidden from view.

Separate digestion of sludge is a subject that can scarcely be dismissed from discussion in this country without some brief reference to experiences at Reading, Pa., such as were given in the *Engineering Record* of August 13, 1910, in the article by

Mr. E. Sherman Chase, describing the operation of those sewage purification works. The plain sedimentation tank there is an unusual one, being an adaptation of some of the structures of an earlier plant. It is cleaned at intervals ranging from six weeks in summer to four months in winter. The sewage is first screened through a device called locally a "segregator," which is essentially a revolving screen of wire cloth with forty meshes per lineal inch.

This device seems to be quite successful in guarding against such a scum as found at Kings Park, which with fresh sewage would probably be noticeable with an Emscher or any other form of settling tank unless arrangements were made to provide for its frequent and systematic removal.

The sludge at Reading is removed by gravity to lagoons made by throwing up dikes about 5 ft. high. During the first two years of operation, about 5 000 cu. yd. of wet sludge were disposed of upon this area. Over the surface a scum forms, beneath which the sludge appears to become quite completely liquefied. No odors are noticeable 200 ft. from the lagoons and the method may be said to be successful so far as offensive smells are concerned, although the limited area of land will soon make it necessary to dispose of the accumulated residual material or to resort to some other method of sludge disposal.

The Reading plant, while of interest in showing what can be done with the digestion of sludge after removal from settling tanks, could, of course, be modified to show considerable improvement if it were desired to construct lagoons in a more permanent fashion and provide them with covers.

The Reading settling tank as operated illustrates one disadvantage of the treatment of the sludge in single compartments that is not found in tanks of the Emscher or Dortmund type. Reference is made to the necessity of disposing of the supernatant liquid at the time of removal of the sludge. At Reading this is ordinarily allowed to enter the river through the adjoining creek unless it should be pumped to the outlet weir so that it could pass on to the filter. In fact, as the tank has but one compartment and the cast-iron by-pass around the tank which was a part of the design has not yet been built, the entire sewage flow enters the river at times of cleaning the tank.

In speaking of the Reading settling tank, absence of odor from the tank and sludge lagoons is not the only feature wherein these works have shown themselves to be satisfactory. There is substantially no odor at the sprinkling filters; in fact,

none is noticeable at a distance of 200 ft. This is due in considerable measure to the fact that the sewage as it passes through the preliminary settling tank and reaches the sprinkling filters is ordinarily fresh and contains dissolved oxygen. It is never septic and, in fact, dissolved oxygen is rarely absent and then only at times just prior to the cleaning of the preliminary settling tanks during the summer months. Indeed, so constant is the presence of dissolved oxygen in the sewage as it reaches the sprinkling filters that very little attention has been given to the important point studied carefully at Columbus, Ohio, as to the amount of oxygen contained in the influent of the sprinkling filters due to aëration of the spray delivered from the sprinkler nozzles. This oxygenation amounts to some 70 to 80 per cent. of saturation, according to the evidence developed at the Columbus Sewage Testing Station (see Johnson's Report, p. 278) and also at the large Columbus works, as stated by Mr. C. B. Hoover in his discussion of Mr. John H. Gregory's paper, Transactions of the American Society of Civil Engineers, Vol. LXVII, p. 374.

Gases from Sludge Digestion.

Dr. Lederer's statements are surely interesting with respect to the absence of hydrogen-sulphide odor in the septic effluents, the effluent of an Emscher tank, as well as from the supernatant liquid of the sludge-digestion chamber of the Emscher tank, although small quantities of hydrogen sulphide were present at times in these various liquids. This statement, of course, is in distinction from the hydrogen sulphide developed in the modified Dortmund tank, in the bottom of which sludge is allowed to accumulate without removal, as described by Mr. Pearse.

Dr. Lederer's assumption that organic compounds through septicization form hydrogen sulphide is in accordance with the views of the writer, who understands that several investigators regard hydrogen sulphide as a cleavage product from proteid matter which has been partially hydrolized by any of quite a variety of species of bacteria. This viewpoint seems to be in accord with the writings of the late Prof. C. A. Herter in his interesting book on "The Common Bacterial Infections of the Digestive Tract." On the other hand, the formation of hydrogen sulphide from inorganic sulphur compounds, so far as the writer knows, is rather an unusual experience and confined to the work of a limited number of species of bacteria.

At the Columbus Sewage Testing Station the reduction of mineral sulphates was not noted in the septic tanks as stated in Johnson's Report, p. 123, although it was noted in the coke strainers (p. 144). There is reason to believe that such reduction has taken place at times in the operation of the large works at Columbus.

While it does not take much hydrogen sulphide to cause a perceptible odor, as stated by Dr. Lederer, it is to be borne in mind that this substance would seemingly be quite promptly oxidized when it meets the atmosphere a short distance from the liquid from which it comes. In Lunge's book on "The Technical Methods of Chemical Analysis," Vol. I, Part 2, p. 888, it is stated that one to two parts by volume in one million parts of air give a very disagreeable odor of sulphureted hydrogen.

Barometric conditions no doubt affect the dispersion of this comparatively heavy gas in the atmosphere.

Mr. Morrill's comments as to the diffusion of sulphureted hydrogen from liquids into the atmosphere are no doubt scientifically correct. They are somewhat at variance, however, with the statements of Dr. Lederer as to experiences at the Chicago Sewage Testing Station.

So far as known, all analyses of gases escaping from septic tanks have been made from samples collected from the confined space above the surface of the liquid, upon which the pressure or vapor density of various gases would be exerted.

Mr. Morrill is also correct in referring to the influence of the size of bubbles formed in the sludge and which by massing together may produce so large a bubble that its buoyancy may carry it to the surface too quickly to allow much practical effect either with regard to the sulphureted hydrogen dissolving in the liquid or combining with iron salts or other compounds producing an insoluble sulphide precipitate.

An examination of the characteristics of various gases produced by the putrefaction of organic matter leads to some interesting comparisons, among which is the striking degree of solubility of sulphureted hydrogen when expressed in parts per million and considered with reference to the comparatively small amount of organic sulphur ordinarily found in American sewages. The following tables show some of these comparisons, although the data are given for pure water without the influence of dissolved impurities or of the several gases upon each other.

TABLE 1.

TABULATION OF SOME PHYSICAL FEATURES OF THE GASES OF SEWAGE DECOMPOSITION.

Gas.	Weight of One Liter. (Grams.)	Density. Air = 1.	Density. Hydr. = 1.	Relative Diffusion (Air = 1.)	Note.*
Hydrogen	0.090	0.0696	1.00	3.83	....
Methane	0.716	0.554	7.97	1.34	....
Ammonia	0.762	0.762	8.59	1.29	7.13
Nitrogen	1.254	0.967	13.92	1.01	....
Oxygen	1.429	1.105	15.90	0.95	....
Hydrogen sulphide	1.523	1.189	17.10	0.95	16.4
Carbon dioxide	1.965	1.529	22.00	0.81	52.1

* Note = vapor tension in atmospheres at 15 degrees cent. (Water vapor =0.017.)

TABLE 2.

TABULATION SHOWING THE APPROXIMATE VOLUMES OF DIFFERENT GASES (PURE) OF SEWAGE DECOMPOSITION WHICH ARE REQUIRED TO SATURATE ONE VOLUME OF PURE WATER AT DIFFERENT TEMPERATURES AND PRESSURES.

Gas.	Atmospheric Pressure. 4° Cent.	Atmospheric Pressure. 15° Cent.	Pressure of 30 Feet of Water. 4° Cent.	Pressure of 30 Feet of Water. 15° Cent.
Hydrogen	0.02064	0.01883	0.0405	0.0365
Methane	0.04985	0.03874	0.09065	0.0751
Ammonia	941.9 *	727.2*	......	......
Nitrogen	0.02130	0.01682	0.0413	0.0326
Oxygen†	0.04397	0.03415	0.0852	0.0664
Hydrogen sulphide	4.044	3.233	7.830	6.272
Carbon dioxide	1.513	1.002	2.943	1.942

* Due to formation of NH_4OH.
† This is for pure oxygen, not atmospheric oxygen.

TABLE 3.

TABULATION SHOWING THE APPROXIMATE WEIGHT IN PARTS PER MILLION OF DIFFERENT GASES OF SEWAGE DECOMPOSITION WHICH ARE REQUIRED TO SATURATE PURE WATER AT DIFFERENT TEMPERATURES AND PRESSURES.

Gas.	Atmospheric Pressure. 4° Cent.	Atmospheric Pressure. 15° Cent.	Pressure of 30 Feet of Water. 4° Cent.	Pressure of 30 Feet of Water. 15° Cent.
Hydrogen	1.86	1.69	3.61	3.27
Methane	35.65	27.7	69.15	53.7
Ammonia	792 000.*	611 000.*	....	....
Nitrogen	26.70	21.1	51.8	40.9
Oxygen†	62.8	48.8	121.8	94.5
Hydrogen sulphide	6 160.	4 930.	11 950.	9 560.
Carbon dioxide	2 975.	1 965.	5 760.	3 810.

* Due to formation of NH_4OH.
† This is for pure oxygen, not atmospheric oxygen.

Mr. W. L. Stevenson * (*by letter*).— Shortly after the publication in the *Surveyor* of Mr. Imhoff's first article describing the Emscher tank, and based upon the sketch shown therein, a tank of this type was constructed at the sewage experiment station then being operated by the Bureau of Surveys of Philadelphia.

Crude sewage was settled for a nominal period of two hours. Due to the very short vertical distance given to sedimentation the effluent was not as low in suspended solids as would have been obtained from a tank of working size. But several of the important basic principles of this tank were established probably for the first time in America.

The complete separation of the settling sewage from the decomposing sludge caused the sedimentation part of the tank to be purely mechanical. No reduction of oxidized nitrogen nor of dissolved oxygen occurred. Nor was there any increase in the free ammonia during the flow through the tank.

The gas which constantly bubbled up through the ventilating funnel was entirely inodorous, and exhibited characteristics of methane.

The sludge which was withdrawn in small quantities at frequent intervals was black, granular, lower in moisture than that from any other tank, having a tarry odor, and dried with much greater rapidity than any other sludge.

The writer believes that the principle of the Emscher tank is a correct one, but that a simpler and cheaper construction must be devised to accomplish the same end. Sewage disposal works are usually located on low ground where the water level is near the surface, and the designing of a deep tank having curved form construction in a water bearing soil adds greatly to the expense.

The use of a horizontal flow Emscher tank with straight side walls, and a sloping bottom terminating in an inverted cone, from the bottom of which the sludge would be withdrawn, might produce the same results at far less cost of construction.

Dr. Rudolph Hering (*by letter*). — Mr. Saville has given us, as I believe, the best account that we have in the English language of the Emscher Sewerage District and of the Imhoff tank. It gives us many interesting details of a subject which for three years I have believed is the most important step that has recently been taken in sewage disposal matters. The sludge

* Assistant Engineer Sewage Disposal, Department of Public Works, Philadelphia.

nuisance has always been the wor t feature of sewage works and to think that at last, after over thirty years' effort, the question has been brought close to a final solution is very gratifying.

The Genossenschaft where Mr. Saville is now temporarily employed is an excellent precedent for the conduct of a similar public work in our country. Some details might be advantageously altered for our different conditions, but in the main the system of organization and operation which has been successfully applied in the Emscher district for a number of years is fair and efficient.

It might be well to add to the discussion that the city of Leeds in recent years erected a large plant with chemical treatment for its sewage, but with the idea that this process is not to be considered a final one. It was stated to me three years ago that it was believed the first process of sewage treatment should be as complete a separation of the suspended matter from the liquid as practicable, which is certainly better accomplished by accelerated precipitation than by plain sedimentation. It is expected that at some future time it will be followed by an oxidation of the effluent. Chemical precipitation has the advantage of removing even fine suspended matter. This process may, therefore, be advisable and more economical where the effluent liquid can be discharged into a body of flowing water or where treatment on land must be confined to small areas. The question of cost may show that chemical precipitation has not passed into oblivion. An interesting question relates to the efficiency of an Imhoff tank when receiving the additional precipitant.

The minimum flow of the Emscher River is stated to be only 190 cu. ft. per second, and it receives the sewage more or less treated from a population of 1 500 000 people. It is surprising that this proportion has been found satisfactory. There are some peculiar conditions in the district which do not prevail elsewhere, and it is difficult to assume that no further purification will be later required. I believe it is proper to await the results of the next few years before revising our former assumptions.

There can be no question, however, that the removal of the larger particles in the suspended matter will make it possible to discharge the effluent into flowing water in much larger quantities than unsettled sewage, without any danger of subsequent putrefaction. It is important also to realize that the removal of this suspended matter practically removes the offensive sludge

deposit in rivers and, therefore, the chief cause of the nuisance from a sewage discharge into them. It is the putrefaction of sludge deposits, of the rising gases and foul particles to be again suspended in the water, which causes the chief trouble to which we object. When we can prevent sludge deposits we have solved the greater part of the difficulty. The liquids, even though containing considerable amounts of dissolved organic matter, are much more readily brought in contact with oxygen and oxidized than when they are in combination with the sludge. This solution seems the proper one to prevent foul docks and similar invitations for deposit in harbor cities.

It is very gratifying to feel that the general opinion is now reverting in one aspect to what it was over thirty years ago when I studied the subject in Europe. In 1880 I saw a concrete-lined open channel carrying sewage with a good velocity from the built-up parts of the city of Oxford in England to the purification works where the sewage was treated before its discharge into the Thames.

At that time it was stated that sewage should be carried in smooth channels and at rapid velocities. Brick work and stone work were frequently objected to because this rough material allowed the sewage to be retained and the sludge particles to become putrescent. With the smooth channel and swift currents, it was remarked, sewage would not smell, and I found a good deal of evidence in England and Germany, in Paris and Vienna, to substantiate this opinion, and I so reported here at home at that time. When the "septic" idea broke in, I felt a great disappointment, because it seemed that a retention of the fresh condition of sewage no longer had a strong backing. It is, therefore, very pleasing to know that the former views are now returning and they already seem to prevail in most cities of Europe.

Regarding odors arising from septic sewage and their persistence in the atmosphere, Professor Bass, Mr. Saville and I, last summer, distinctly perceived the odor of sulphureted hydrogen at the Wilmersdorf purification works near Berlin for a distance of over a mile from the outlet of the delivery pipe. The sewage had flowed many miles in a pipe, — about, I believe, 20 in. in diameter, — and at a very slow velocity. It was thoroughly septic and when discharged had a very strong odor, reminding me of a similar point at the Saratoga Springs (N. Y.) sewage disposal works, where the odor is also perceptible for quite a distance, and which was the cause of our recommending the reservation of a wide strip of land around the large Baltimore (Md.) sewage works.

Dr. Spillner.* — Mr. Fuller has raised the point about the development of H_2S, and this question has apparently aroused much interest since Mr. Phelps, Dr. Lederer and others have also had considerable to say about it. They ask why the Emscher tanks in Germany produce such remarkably small amounts of this gas, and whether similar results may be expected under other local conditions.

In order to answer this it is necessary to understand clearly in what technical respects Emscher tanks differ from ordinary septic tanks. In septic tanks the liquid sewage and the deposited sludge undergo decomposition together, while in Emscher tanks (after the sludge chamber becomes ripe) practically nothing but the deposited sludge decomposes. It therefore seems that the septicization of the organic and colloidal substances in solution in sewage is the main cause of the development of H_2S, and that this gas is produced only in much smaller quantities from the suspended organic solids.

Practical experience supports this opinion. If the "flowing-through-time" in an Emscher tank (normally one to two hours) is sufficiently lengthened for the sewage to become septic (in warm weather this requires about five hours with our sewages), with the result that similar conditions to those in septic tanks are produced, the same plant which was formerly odorless will develop much H_2S and may smell very bad. This experiment may be made with any Emscher tank installation. Further, if an Emscher tank which shows no development of H_2S is emptied completely (this should of course not be done in practice), or in large part, and is then placed again in operation, the sludge-decomposing room becomes filled with fresh sewage. After some hours H_2S begins to develop, and lasts till the organic matter of the sewage in the sludge decomposing chamber is completely rotted out. I can speak personally of practical examples of both of these cases. It would therefore seem that by preventing septicization of the dissolved organic matter the development of H_2S in appreciable amounts can be avoided.

A theoretical explanation of why more H_2S gas can be produced by the dissolved organic matter in sewage than by the organic matter in the sludge follows.

1. Sewage usually contains much more organic matter in solution (and colloid solution) than in suspension. This is shown by averages of all the sewage analyses made up to October, 1910,

* Chemist, Emschergenossenschaft, Essen, Germany.

at the plants of the Emschergenossenschaft in Recklinghausen, Bochum and Essen N. W. (Figures are in parts per million.)

	Reckling-hausen.	Bochum.	Essen N.W.	
Organic matter in filtered sample of raw sewage	229.6	248.8	416.4	
Organic matter in suspended solids in raw sewage	259.3	186.9	261.6	
Total organic matter in raw sewage	488.9	435.7	678.0	1602.6
Organic matter in fresh sludge deposited in tank *	185.8	130.5	176.0	492.3

* Equals difference between organic suspended solids in raw sewage and effluent of tank. (See table of analyses on page 21.)

If the dissolved organic matter should contain no more organic sulphur per unit than that in the deposited fresh sludge the possibility of H_2S developing in the sludge chamber of an Emscher tank would seem to be only about $\frac{492.3}{1602.6} = 31$ per cent. of what it is in ordinary septic tanks.

2. The amount of organic sulphur in the deposited sludge is, however, much *less* than in the "not-capable-of-settling" (dissolved, colloidal, fine suspended, etc.) organic matter. I am not yet in a position to give definite proof of this (by actual analyses); but it is well known that in the digestion processes of man and other animals the sulphur-containing products of the digestion of albuminous matters (eaten by the animals) are found for the most part *not* in the fæcal matters but in the urine. In sewage one would therefore not expect to find these organic sulphur compounds in the sludge ("capable-of-settling" suspended solids) but rather in solution. Because of these considerations the above-mentioned 31 per cent. should be considerably decreased.

The foregoing seems to me to be a good explanation of why there is less H_2S developed in Emscher tanks than in ordinary septic tanks.

Some people have suggested that our good results with these tanks in Germany have been largely due to iron in the sewages. In this connection it will be of interest to mention that analyses (thus far available) of the sewages treated show less than 1 part per million of iron (total iron as Fe) at four of our smaller plants handling principally house sewage, and quantities varying from 1 to 25 parts per million at the larger works where the sewage contains manufacturing wastes.

Mr. Saville. — I have been much interested in what Mr. Fuller and the others have said about the possibility of odors arising from tanks of the Imhoff type, due to the production of H_2S in the sludge decomposing chamber. Experience with the formation of this gas and its escape into the atmosphere in sufficient amounts to create a nuisance has been extremely varied in the case of ordinary septic tanks. The opinion is therefore expressed that we must face the possibility of trouble of similar nature with the Imhoff tank, especially in cases where the sewage contains much sulphur but only small amounts of iron (or other ingredients that would unite with the H_2S and keep it in the tank).

I shall not attempt to explain just why objectionable odors are *not* noticed around the tanks of this type now operating in Germany — for the most part in thickly settled localities — or to predict definitely what our experience with full-sized plants is likely to be in America. The causes of production of odors at sewage disposal works need further and careful study; but in discussing this matter (so far as the Imhoff tank is concerned) there are a few important points which ought not to be lost sight of. (1) We must not forget that the sedimentation chamber and the sludge decomposing chamber are two distinct and practically separate portions of the tank. (2) The flowing sewage (containing all matters in true solution and in colloidal condition as well as those suspended solids which do not settle readily) passes rapidly through the sedimentation — usually in one or two hours. *It does not come in contact with the deposited sludge* or gases of decomposition, and leaves the tank as fresh as when it entered. Is it possible under these conditions, even with a sewage containing large quantities of mineral sulphates or other sulphur compounds (most of which are said to exist largely in solution), that H_2S can be formed in appreciable amounts? In the case of tanks carefully designed and operated with a view to avoiding septic action in the sedimentation chamber, it would seem as if we need not fear odors of H_2S formed in the sedimentation chamber from any substances carried by the sewage in solution and in colloidal condition or in the form of fine suspended solids which do not settle out in the "flowing-through-time" of two hours. (3) The portion of the iron salts or other ingredients of the sewage which are in solution and colloidal form, or in suspension but not "capable-of-settling," cannot be depended on to precipitate H_2S, which may be produced in the sludge-decomposing chamber as a result of the decomposition of the

sludge. This is self-evident, as the flowing sewage is entirely separate from the sludge chamber. (4) The sewage in the sludge decomposing chamber is extremely limited in quantity and is not renewed since there is no inflow from the sedimentation chamber. If, therefore, H_2S is formed from the decomposing sludge (and is not all retained in the sludge as a result of precipitation by iron salts or other compounds entering the sludge chamber in the suspended solids which have settled out of the flowing sewage), it would soon saturate this small volume of water to the extent of becoming noticeable.

Mr. Eddy has shown a clear appreciation of the above-mentioned points in suggesting that the Imhoff tank is especially fitted to treat sewage containing manufacturing wastes because the quantity of sewage (containing spent chemicals) which is in contact with the sludge is comparatively small, and there is not much likelihood of the chemicals interfering to any extent with the processes of decomposition.

When a tank is first placed in operation the conditions are somewhat different and it is possible that odors can temporarily be detected in the immediate vicinity of the tank due to the breaking down of the organic matter (and perhaps mineral sulphates) in the sewage standing in the sludge room. It does not take long, however, for all the putrescible organic matter in this sewage to become completely decompcsed.

The point has been emphasized in some of the discussions that there is nothing specially new in the ideas upon which the type of tank under consideration is based. With any branch of science each step in advance is usually a development of, and an improvement on, the work already done; but whatever the facts may be, it is certainly true that all of us having to deal with sewage disposal problems are much indebted to Dr. Imhoff for the careful study of the design and operation of sewage-clarification tanks which he has been carrying on for the past six years.

The success of the sewage disposal works of the Emschergenossenschaft is due in part to a thorough understanding of all the factors affecting the design of the tanks and to the expert supervision which they receive after being placed in operation. I do not think it is the result of special characteristics of the sewages treated, and this opinion is perhaps borne out by the good results already obtained (in small tanks) with representative American sewages. It will be interesting to watch the work of the first full-sized installations in this country, and, in the event of poor results, to determine to what extent they are due to

faulty design and unintelligent operation. Sewage disposal plants should certainly be made as nearly "fool-proof" as possible; but we must continue to expect trouble of one kind or another wherever they are placed in charge of persons who have had no proper training to fit them for the work.

The Imhoff tank, because of the good results it has given thus far, is not necessarily to be considered a cure for all evils. Mr. Phelps and others have already emphasized this. Every sewage disposal problem must be studied on its merits with full consideration for local conditions. This principle applies likewise to details of design. Mr. Gage has perhaps misunderstood me in saying that I consider a depth of 25 to 30 ft. to be an essential feature of this style of tank. Deep tanks have numerous advantages over shallow ones. Among them the following may be mentioned: 1. A larger ebullition of gas in the sludge chamber per square foot of horizontal cross-section. This tends towards a more thorough mixing of the sludge deposits. 2. Higher and more uniform temperature in the sludge chamber. 3. A greater depth of sludge with consequently less likelihood of drawing out partly decomposed sludge at times of removal. Other advantages might also be mentioned. The conditions in deep tanks tend to produce sludge containing less water (it therefore requires less space) and less undecomposed organic matter than is the case with shallow tanks. Furthermore the decomposition of organic matter in the sludge is probably more rapid in deep tanks. But at some places deep tanks may prove impracticable.

If shallow tanks are used the volume of the sludge decomposing chamber should be greater than with deep tanks; because, as already pointed out, the rate of decomposition of the sludge is likely to be slower — thus requiring more time, and, further, due to the fact that the sludge may contain more water and thus occupy more space. The sludge when withdrawn may not dry so quickly as that removed from deep tanks because of higher water content and less gas. The area of the sludge beds should therefore be greater.

Mr. Frederic H. Bass (*by letter*).*— The writer takes pleasure in adding his testimony to that of the author of the paper. His observation of the Imhoff tanks in the Essen district left nothing but a favorable impression, which was strengthened after having seen the Travis tank at Hampton, England.

The dreams of Victor Hugo and his enthusiastic if unin-

---

* Director Engineering Division, Minnesota State Board of Health.

formed followers seem to have been partially realized: sewage has been treated in a practical way so that the solids can " support vegetation," to quote Mr. Saville's closing words. The sludge problem seems to have been solved, or at least the proper lines for its solution indicated by this tank.

The history of the evolution of the design of the tank is interesting. The separation of sludge from the sewage in the tank undoubtedly originated in America. England applied the idea, and Germany perfected it. This is surely a testmonial to the success of the Teutonic methods of careful, deliberate and patient investigation. The last word has not been written in regard to this tank or in regard to further processes of sewage purification, and the need for investigation along lines for the more efficient and economical treatment of tank effluents seems to the writer a most pressing one.

Mr. Phelps's statement that the large cities can advantageously dispose of their sewage without tankage previous to filtration is interesting. The writer would like to hear Mr. Phelps make further comparison as to the methods of removal of solids from sewage, viewed from an economic and esthetic standpoint. The writer's observation leads him to believe that ordinarily this form of tank in removing the solids from sewage delivers them in a form more satisfactorily and more economically disposable than any other type of construction. The use of screens is not decried, but the belief is asserted here that tanks as well as screens have their place, although pe aps they are less important in the larger plants.

One advantage of this tank is particularly worthy of note, and that is in connection with combined sewer systems. With a single story tank the storm sewage must be diverted from the tank on account of the disturbance caused in the process, but in the two-story tank, by-passes are often unnecessary and the sedimenting value of the tank can be to a great extent realized during storm flow.

Mr. Fuller, in discussing the Kings Park plant, makes the statement that an attendant visits that plant once a day for a few minutes, and then says that, in the case of an Emscher tank, the regular employment of a laborer would be necessary to attend to the sludge bed. This is not a fair comparison because the cost of handling the sludge in the ditches of the two-tank system and Kings Park is not referred to, while the handling of sludge is referred to in the case of the Imhoff tank; moreover with a population of 3 000 or 4 000, the amount of sludge dried

on the bed should not be over 0.1 cu. yd. per day., which, if handled daily, or even once a week, could hardly call for the continuous employment of a laborer.

At a plant in Baltimore treating about 2 500 000 gal. per day, recently visited by the writer, the double tank system was used and the odor from the sludge was extremely disagreeable at a distance of several hundred feet. The odor arising from ground used in the trench treatment of sewage has been noticed by the writer to be quite offensive, notably at Hampton and Birmingham, England. On the other hand, at none of the sludge beds in the Emscher district was any odor perceptible, either at a distance of 3 in. or greater.

The writer agrees with Mr. Fuller that the Emscher tank can probably be modified in its design in many cases for the sake of economy, although he would not, as Mr. Stevenson suggests, use the inverted cone, as ordinarily the lower walls are more easily constructed in cylindrical or rectangular form. With the more dilute American sewages, the lower compartment of the tank might be considerably reduced in size and still contain sufficient sludge storage capacity.

[Note.—Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by Sept. 15, 1911, for publication in a subsequent number of the Journal.]

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVII. AUGUST, 1911. NO. 2.

THE HUDSON SEWAGE DISPOSAL SYSTEM AND THE DISASTROUS EFFECTS OF WOOL WASTE.

BY FRANK A. BARBOUR, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Presented to the Sanitary Section, March 1, 1911.]

THE incapacitation, in 1908–1909, of the sewage disposal plant of the town of Hudson by the admission of wool waste illustrates, although in a rather unusual manner, the disturbing effect of one kind of trade effluent on the operation of purification works, and calls attention to the necessity for discrimination by those in charge of sewerage systems as to the character of such trade effluents to be admitted to the sewers.

In 1908 the local board of health ordered the Hudson Worsted Company to connect with the public sewers and so remove its waste from the Assabet River, into which stream it had previously been discharged. The Board of Public Works, in granting the permit, stipulated that an adequate settling tank should be provided for treatment preliminary to the entrance of the waste into the sewer, the company stating orally at a conference the probable quantity to be handled.

The connection with the sewer was made August 21, 1908, and within a few days the effect of the wool fats on the operation of the sand filters became noticeable, and during the winter of 1908–1909 the beds slowed down to a point where they were continually covered with liquid to a depth of several feet. Relief was sought by the town in the form of an injunction requiring the Worsted Company to remove its waste from the sewers,

the company replying that it had connected by order of the local board of health and denying its responsibility for the failure of the disposal works to effect purification, which, it alleged, was due to improper management of the plant.

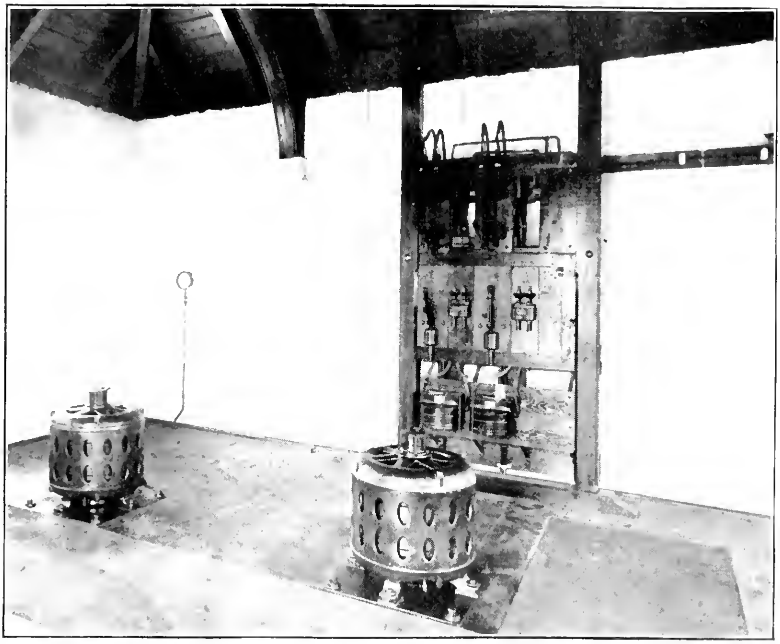
As a result of covering the sand with wool fats, nitrification practically ceased, and the filtrate differed but little in appearance from the raw sewage. Consequently pollution of the river followed, and Mr. A. D. Gleason, a manufacturer of woolen cloths, located on the river one and three-fourth miles below the disposal plant, brought suit against the town of Hudson and the Hudson Worsted Company, alleging such contamination of the stream as to render impossible the use of the water in dyeing operations. This action on the part of Mr. Gleason diverted attention from the application of the town for an order requiring the removal of the wool waste from the sewer, and this waste continued to be discharged into the public system until September, 1909, when the grease recovery plant, to be subsequently described, was ready for use.

In answer to the application of Mr. Gleason for an injunction preventing further pollution of the stream, the Hudson Worsted Company replied that it was having studies and plans made for the treatment of its waste, and that an adequate plant would be put in operation August 1, 1909, — a date subsequently changed to September 1, — and it further agreed to construct at the Gleason works a temporary sand filter for the improvement of the river water used in these works, until the grease recovery plant should be in operation. The town of Hudson, on its part, undertook, in September, 1909, the enlargement of the disposal works.

The case of Gleason *versus* the town and the Worsted Company for damages resulting from pollution of the river was submitted to a Master, and after running through many days was finally practically abandoned.

When the disastrous effect of the wool waste on the disposal plant was first brought to the attention of the Worsted Company, the attitude of this company was that the town must make provision for the disposal of its waste by such modification of the disposal plant as might be necessary, denying any obligation to submit the waste effluent to such preliminary treatment as would render its purification possible by ordinary methods in conjunction with the normal town sewage. Later, with the advent of a lower proprietor on the stream as plaintiff, this company, as has been stated, realized that it must treat its

Pumping Station.

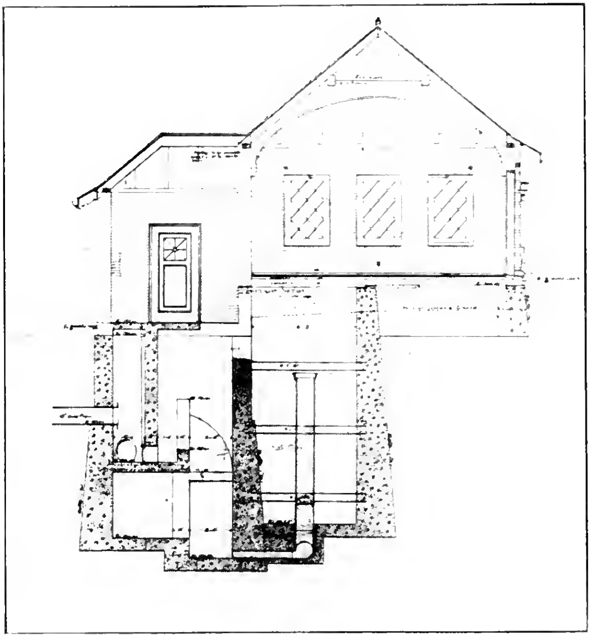


Interior.

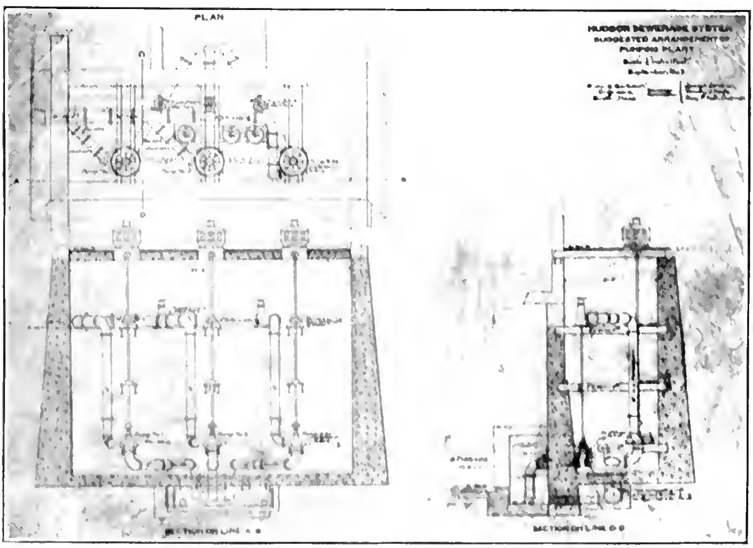
Exterior.

Hudson Sewerage System.

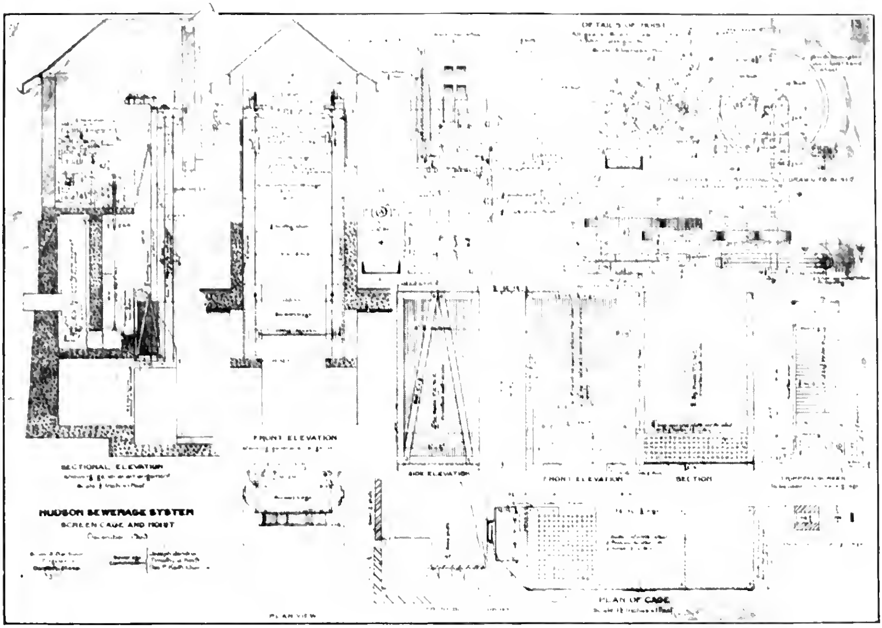
Pump Well and Station.



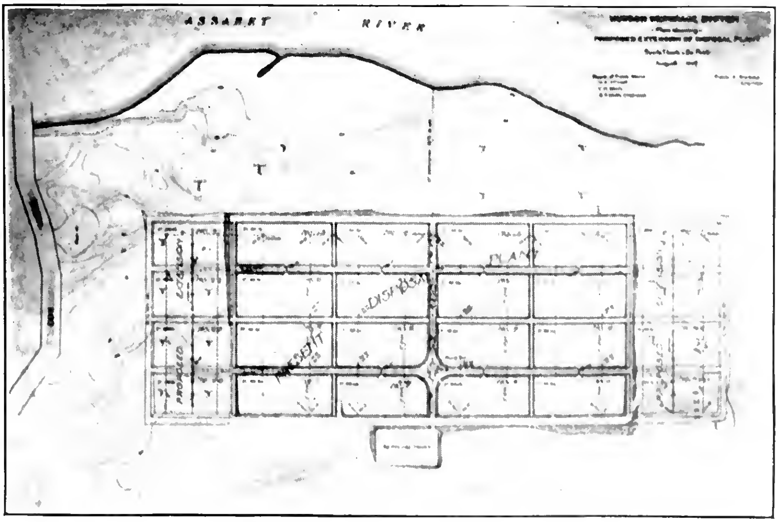
Section.



Plan and Sections.



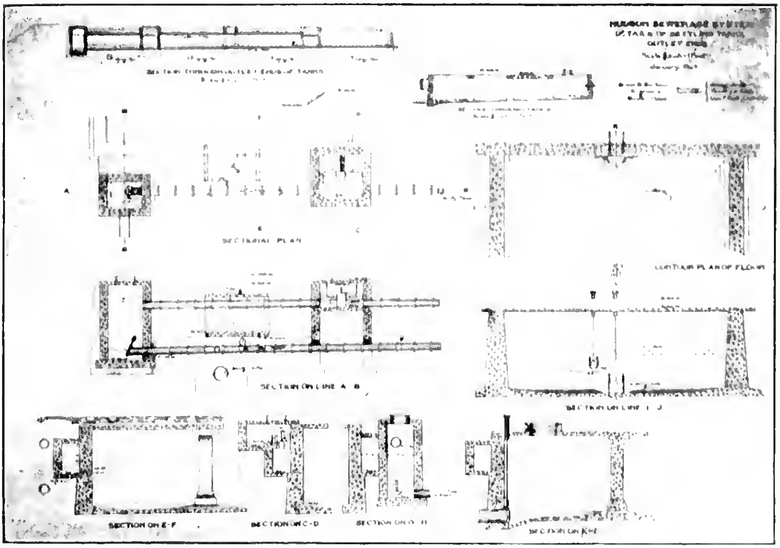
Screen Cage and Hoist.



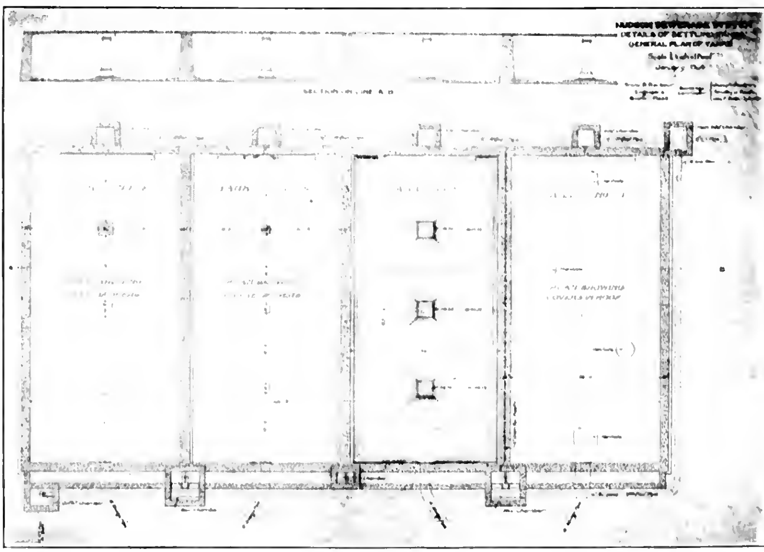
Plan of Disposal Plant.

Hudson Sewerage System.

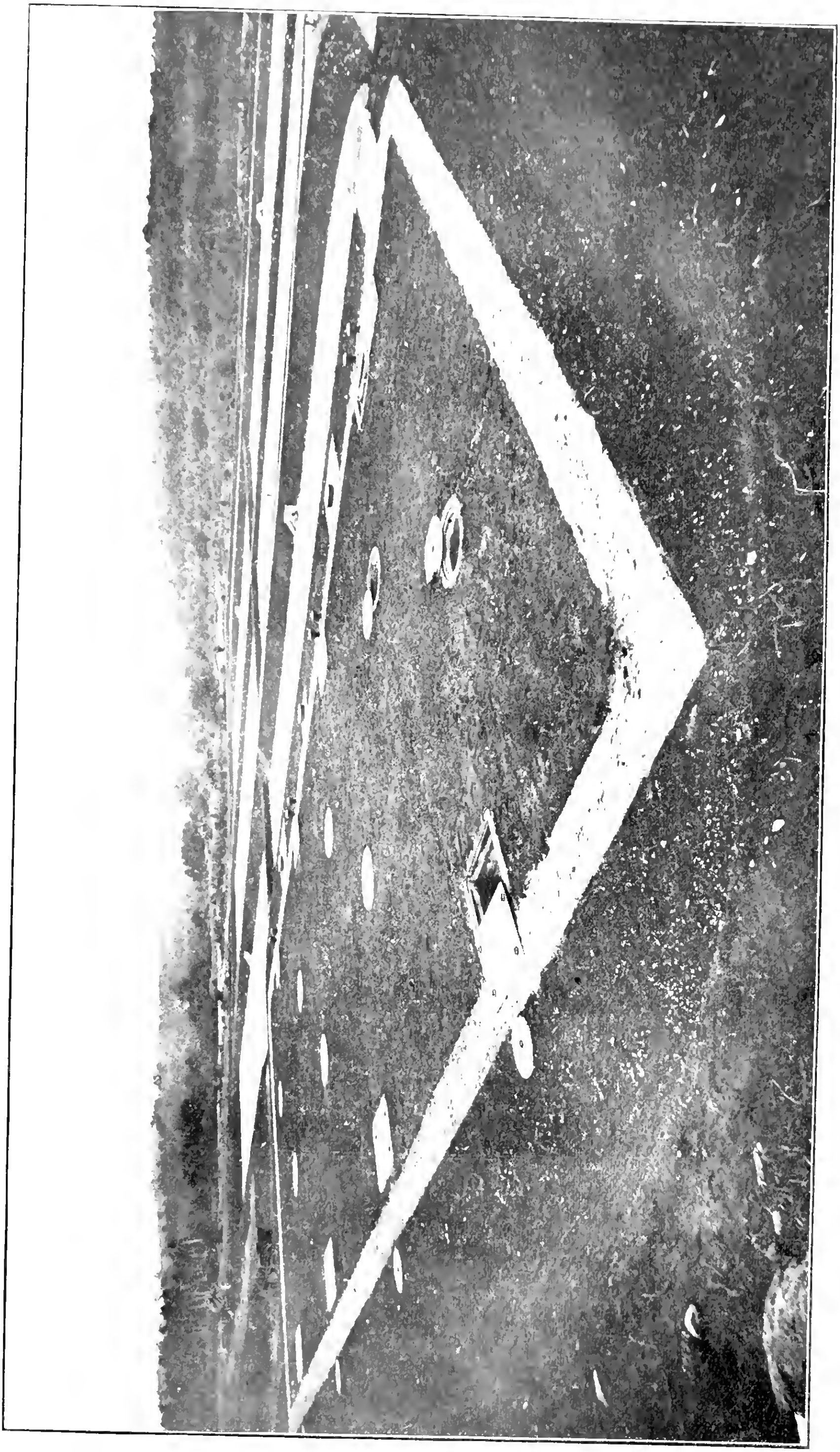
Settling Tanks.



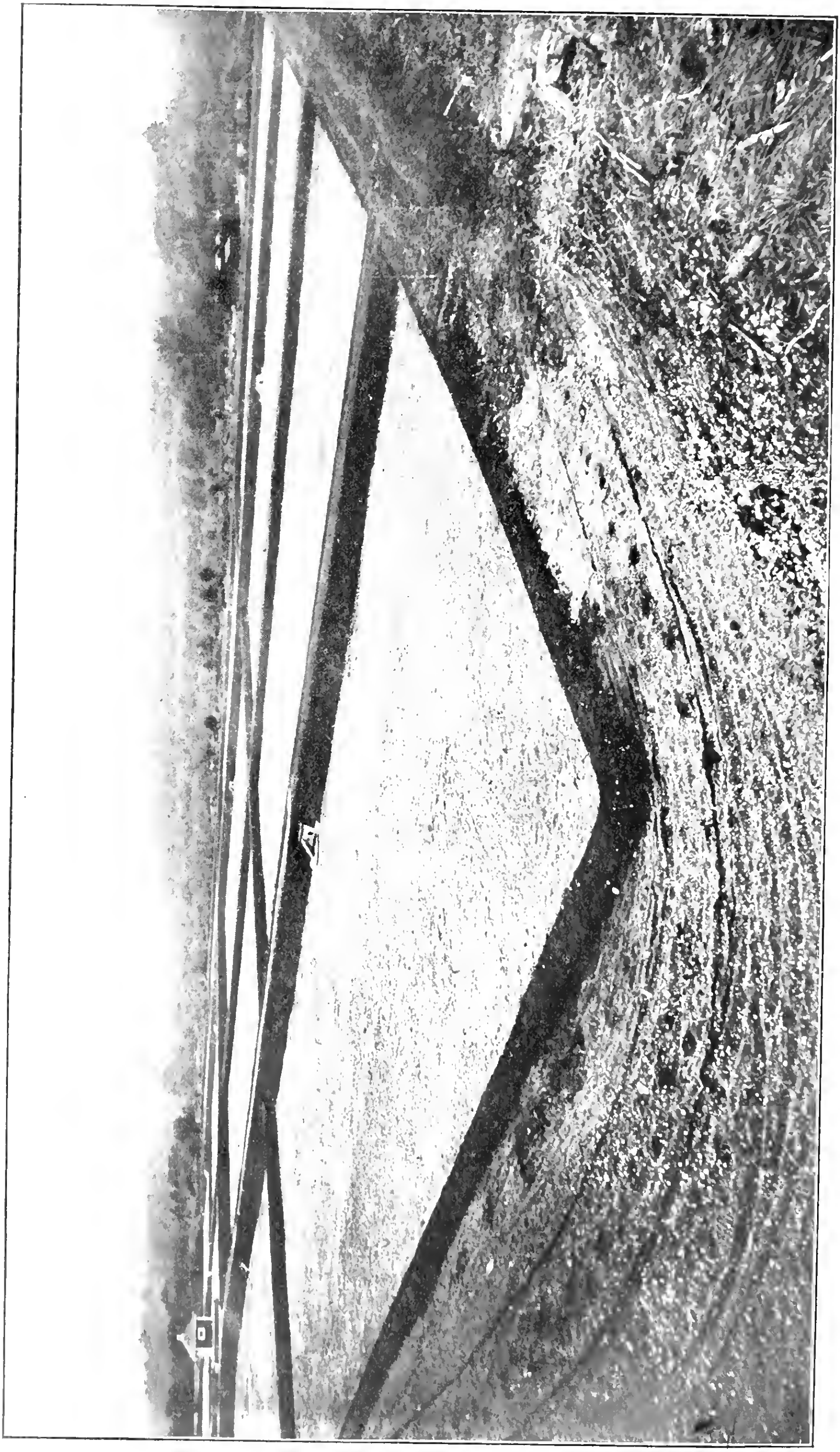
Details.



Plan and Section.



Disposal Plant (looking over top of settling tanks).



Disposal Plant (looking across filters).

effluent and, once convinced of this, immediately turned to the possibility of obtaining some return from the necessary expenditure by recovering the fats. To work out this problem, Mr. Weston was retained and to-night he will describe the works constructed and the results obtained to date.

Before attempting a more detailed statement of the effect of the wool waste on the operation of the disposal plant, a brief description of the Hudson sewerage system may be of value. Hudson is a town of 6 700 people, located on the Assabet River, which at this point has a watershed of seventy-five square miles area. The installation of sewers was begun in 1903, and practically completed two years later. The sewage flows to a pump well of 10 000 gal. capacity, first passing through a screen of ½ in. square bars placed 1 in. on centers. From the well the sewage is lifted by centrifugal pumps of 500 gal. per minute capacity, electrically driven, and started and stopped automatically by switches actuated by floats in the pump well. The pumping apparatus is installed in duplicate. The sewage passes from the pump through a 12-in. cast-iron force main, 5 000 ft. long, to a disposal plant adjacent to the river and 1.6 miles below the center of the town.

The disposal works, as originally constructed, included settling tanks of 300 000 gal. capacity in four units, and six acres of filtration area divided into fifteen sewage beds of ⅜ acre each, and one sludge bed, the latter placed directly in front of the settling tank and with its surface at such an elevation as to permit the discharge of sludge from the tanks. The sand varied in effective size from 0.10 to 0.60 mm., and perhaps averaged 0.30 mm. Two lines of underdrains were laid in each bed at depths varying from five to six feet below the surface, all drains being connected with a single main outlet leading to the river.

The sewage, after passing through such of the settling tanks as may be in use, flows over an aërator and thence to a dosing tank, from which it is intermittently discharged in doses of 13 000 gal. at a rate of 3.5 cu. ft. per second. An apparatus in the dosing tank automatically shifts the discharge through a cycle of four outlet pipes, through each of which four beds may be reached. The size of dose may be changed, but that usually applied is equivalent to a little more than one inch in depth on the sand surface, and experience has proved that the rate of discharge — equal to 1 cu. ft. per second for each 5 000 sq. ft. of area — will effect, on the ordinary sand bed, good distribution.

The system was first used in November, 1904, and the

number of connections gradually increased to about 500 in 1910, serving perhaps 3 000 people. In addition to the Worsted Company, there are five other manufactories, — three shoe shops, a rubber factory and tannery. Only the latter, which connected with the sewer June 1, 1909, is of any significance in the present discussion. From this plant about 50 000 gal. are discharged daily into the sewers, the liquid first passing through a hopper-bottomed tank of 10 000 gal. capacity, which provides two hours' sedimentation, and by which a considerable percentage of the suspended solids is removed. This waste liquid has an alkalinity of 80 parts per 100 000, a fact of interest in connection with the possible neutralization of the acid effluent from the treatment plant of the Worsted Company.

From 1905 to 1908 the amount of sewage gradually increased, averaging about 175 000 gal. per day, and varying from this amount in different seasons by reason of leakage. The method of operating the disposal plant included the use of three of the four settling tanks and the application of the sewage to all the beds in turn during the summer, except four which were used each winter and allowed to remain idle during the remainder of the year. This was not the best possible practice, as the application of 175 000 gal. per day to four beds, or one and one-half acres of sand area, resulted in too high a rate, while the bringing into use each spring of all the other beds did not furnish the conditions necessary for the proper development of nitrification. The filtrate was, however, throughout of good quality, although not as good as would have been obtained by more regular use of the available area and greater care in the removal of weeds and the grading of bed surfaces.

As already stated, the Hudson Worsted Company connected with the sewer August 21, 1908. On October 15, the writer was called in to advise the authorities as to the best means of meeting the emergency resulting from the entrance of this wool waste into the system. In less than two months the filters, on which it had previously been difficult to properly distribute the sewage, because of the coarseness of the sand and its rapid disappearance below the surface, had become so clogged as to make it impossible to pass through the six acres of beds 200 000 gal. per day without allowing the sewage to stand a foot or more deep above the sand.

The Hudson Worsted Company receives wool in the fleece, and the finished products are tops, noils, comb waste and card waste. The operation of interest to the present discussion

is the scouring and rinsing of the wool in two sets of bowls by solutions of alkalies and vegetable soaps, at temperatures varying from 50 to 130 degrees. These bowls, which have a capacity of about 8 400 gal., are generally emptied three times daily, the period of discharge taking less than thirty minutes and the total daily outflow being about 25 000 gal. At the time of connecting with the sewer an addition was made to the small settling tanks previously in use, and during the period when the waste entered the sewer the total capacity of the settling tanks was about 6 000 gal., or less than the contents of the two sets of bowls. It is evident, therefore, that the resulting sedimentation could do little more than remove the heavier dirt and the grease immediately coagulated by the falling temperature and left in the settling tank when discharge from the bowls ceased.

The shrinking of wool in scouring, depending on its character, ranges from 25—65 per cent., with an average of perhaps 40 per cent. Analyses of the effluent after passing through the settling tanks at the mill showed an average of 2 000 parts per 100 000 of total residue, and 800 parts of fats, equal for the 25 000 gal. outflow to 4 000 lb. total residue and 1 600 lb. fats per day entering the sewer.

Early in 1908 the Hudson Water Department, owing to a shortage of supply during the preceding season, completed the installation of meters, so reducing the consumption that the sewage during the summer of this year amounted to only 150 000 gal. daily. With this the 25 000 gal. of wool waste was mixed and the resulting compound as it entered the settling tanks at the disposal plant contained 300—400 parts total residue and 150—250 parts fat, about one half of these amounts being removed by sedimentation in the settling tanks and the remainder passing on to the filters. Compared with these figures, average sewage contains about 60 parts total residue and 5 to 10 parts fat per 100 000 parts.

The result of applying this abnormal liquid to the filters was the filling of the interstices of the sand with fats and other matter to varying depths, depending on the size of particle, the exclusion of the air necessary for purification and the consequent disappearance of nitrates and the increase of iron and development of its attendant evil, Crenothrix, in the underdrains. Purification practically ceased, and the filtrate, except for the mechanical straining out of suspended matter, differed but little from the sewage, containing at times more than 10 parts of fat. During the winter of 1908–1909 the difficulty of

passing the sewage through the filters increased, and in the spring all the beds were covered to a depth of several feet by liquid, which could only be removed by cutting trenches through the embankments and draining on to adjacent land.

As soon as the filters were uncovered it became apparent that either a considerable depth of the sand must be removed and replaced or an additional area of filters must be constructed if the town was to be in a position to purify the sewage and meet its obligation to lower proprietors, and particularly to the plaintiff on the river below.

Samples of the surface scum on the beds showed it contained 15—25 per cent. fats, and that in samples of sand collected 3 to 6 in. below the surface there were 10—1 500 parts of fat per 100 000 parts; in samples taken 1 ft. below the surface, 5—200 parts; 2 ft. below the surface, 1—200 parts; and 3 ft. below the surface, 3—50 parts; the variation of the amounts at different depths being due to varying degrees of coarseness of the sand in different parts of the field. In filters under normal conditions the fat contents vary from a maximum of 50 parts per 100 000 at the surface to 5 parts at a depth of 2 ft.

Evidently a removal of the clogged sand and the replacement of new sand involved a considerable undertaking and one in which it would be difficult to determine in actual work where to draw the line. On the other hand, there was the possibility that, by rest, the old filters would recover, and that if a sufficient new area could be constructed to care for the sewage, for a time, at an expense not much greater than the cost of removing and replacing sand in the old filters, this would be the best investment. Such a course was accordingly followed and 3 acres of sand filters were added by constructing four beds of $\frac{3}{8}$ acre each at the east and west ends of the disposal field.

Up to September 1, 1909, when the wool waste was removed from the sewer, the sewage had been applied to the old beds, which by frequent scraping were kept in such condition that the applied liquid passed through, but with little purification. Soon after the removal of the wool waste from the sewers the beds began to improve, the accumulated fats gradually disappearing, first at the surface, and more slowly at lower depths, until at the present time the sand has largely recovered its former capacity for purification. This change is evidenced by the nitrates of the filtrate, which, while practically absent in 1909, increased in 1910 to a maximum of 2.37 parts per 100 000, and by the decrease in free ammonia and iron, the former from a maximum of 8.8.

parts in 1909 to 0.72 parts in 1910, and the latter from a maximum from 9.6 parts in 1909 to 0.025 parts in 1910. The analyses of the sewage, tank effluent and filtrate are shown in greater detail in a chart which was made up from figures kindly furnished by Mr. Goodnough, of the State Board of Health. The recovery of the filters, which has been accomplished by keeping the surface open by frequent raking and applying sewage from time to time, suggests that if there had been domestic sewage sufficient to adequately dilute the wool waste, and larger area of filters, the difficulty of purifying the combined liquid might not have occurred.

The grease recovery plant having been placed in commission by the Worsted Company, the question arose as to whether the resulting effluent was of such character as to justify its admission to the sewer, and as to what standard should be required by the town as a condition on which this effluent would again be received into the system. In this connection it should be mentioned that in the 1909 session of the Legislature, and largely as a result of the visit of the Drainage Committee to Hudson, an act was passed, Chapter 433, Acts of 1909, by which the local authorities in charge of sewerage systems are authorized to make such regulations as to prevent the entrance of any substance which may tend to interfere with the flow of sewage or the proper operation of a sewerage system or disposal works.

After some consideration the Board of Public Works requested the advice of the State Board of Health in regard to a standard for the effluent of the Worsted Company plant, and this board recommended that the fats be limited to 25 parts and the acidity to 100 parts per 100 000. However, before it was demonstrated that this standard could be reached, an injunction was granted Mr. A. D. Gleason restraining the Worsted Company from again entering the public sewers of the town of Hudson, and the effluent from the grease recovery plant continues to run into the river. This effluent has for eight months averaged well below the required standard for fats, but has exceeded the limit of acidity set by the town, a result difficult to avoid without final neutralization by lime. There is ample alkalinity in the river to counteract the acidity of the effluent, and there appears to be no reason why it should not continue to enter the stream.

Several interesting general considerations are suggested by the Hudson case. In the first place, why should a city or town undertake to dispose of liquid manufactural waste any more

than the waste from other manufactural processes which happens to be in solid form? Certainly this can only be done without injustice to other taxpayers when the trade waste is no more difficult or entails no more expense to treat than ordinary sewage, and then only when the return to the community is so determined as to express the relative benefit derived by each user of the sewer. Again, how can local authorities be expected to know the character of manufactural waste or the plant necessary for its treatment? If admitted to the sewer, it is sometimes difficult to effect its removal, and, as shown by the Hudson incident, great damage can be done in a short time. Further, the additional expense in operation resulting from the admission of trade waste is not easily figured, nor is it easy to demonstrate that the standard set for the effluent before admission to the sewer is not reached. Conditions similar to those in Hudson resulted in the Westboro disposal system from the disturbing effects of the discharge of a yeast factory. In Peabody at the present time it is apparently impossible so to prevent the entrance of solid matter from tanneries as to permit the maintenance of a clean trunk sewer. The authority granted sewer commissioners and the State Board of Health to order the removal or to require the treatment of trade waste is a step forward, but how is the necessary treatment to be worked out? At present manufacturers expect their waste to be taken care of, and even when convinced that some method of preliminary purification is necessary rest their case on the statement that, when shown what they should do, they will do it. The fact that the burden of the problem rests on the manufacturers should be more clearly made apparent, and this particularly because of the doubt as to whether manufactural waste can be legitimately considered sewage, and whether a town has a right to take under eminent domain the additional land necessary for its disposal, or to discharge an effluent into a water course more or less influenced by its admixture with the sewage, or, perhaps, to levy assessments based on the additional cost resulting from its entrance into the system.

Further, in the opinion of the writer, the addition of trade waste should be determined by its character and without regard to the quantity to be discharged or the possible counteracting effect of some other constituent in the town sewage. To illustrate: An amount of wool waste small in proportion to the domestic sewage may not seriously interfere with the purification of the combined liquid, but having established the pre-

cedent of admitting a small quantity from one manufacturing plant, what is to be done if another plant starts up and makes application for the admission of another small amount of similar waste? Again, if in some other type of plant an alkaline effluent is being discharged which might counteract the acidity of another effluent, how can it be known that this first plant will continue to operate? Still further, while there is no doubt that, when mixed with a sufficient quantity of domestic sewage, almost any trade waste can be purified, which one of several manufacturers would be responsible for the limit being reached? At Peabody the discharge of the untreated waste from a considerable number of tanneries probably would not seriously interfere with the maintenance of the intercepting sewer, but, when fifty tanneries connect, the result is such that all must be required to provide preliminary treatment.

In short, the only logical and safe basis is to admit to the sewer such trade effluent as, independent of its quantity, or the quantity or character of the town sewage, will have no disturbing effect on the operation of the municipal system.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1911, for publication in a subsequent number of the JOURNAL.]

THE DISPOSAL OF MANUFACTURING WASTE.

By R. S. Weston, Member Boston Society of Civil Engineers.

[Presented to the Sanitary Section, March 1, 1911.]

The problem of manufacturing waste disposal must necessarily in the future demand a good deal of attention on the part of those who have to do with municipal problems. The subject is equally important to the manufacturer, but has been little discussed from his standpoint.

No manufacturer pollutes a stream from choice. On the other hand, he very rarely has a proper conception of the relation between his business and the character of the water in the stream on which his factory may be located. For example, streams which are good for the water supply of paper and textile mills often have attractive banks and drainage areas. They attract population and pleasure seekers. Naturally factories follow. Factories in turn attract population, so that where factories are, there will the people be gathered together. Both have a right to use the stream properly. They have a mutual interest in the prosperity of the locality. It is not necessary to turn the banks of every stream into a park, and only certain streams can be used for sources of drinking water supplies, as it is absolutely impracticable under modern conditions to restore streams used for manufacturing to their pristine purity or to maintain them in a condition fit for drinking. However, the water can be filtered and the waste and sewage purified.

But if the stream water be filtered or even abandoned as a source of water supply, there is a desire on the part of the manufacturer to use the stream, and desire on the part of the community to have manufacturing processes create no nuisance and cause no interference with the use of the stream for pleasure purposes. It seems that some scheme must be devised by our legislators and sanitary authorities to make such adjustments in laws and conditions that all may use the streams, each individual respecting the rights of all others.

The conditions confronting many manufacturers are rather onerous. Others are, unfortunately, rather neglectful of their obligations. Many manufacturers fail to consider the cost of

waste disposal as part of the manufacturing cost, to be included in the cost of the goods just as much as the labor cost; and although they are at a disadvantage in manufacturing where it is necessary to spend money for the disposal of waste, there is compensation in that the necessity for waste disposal usually arises in the vicinity of a good market for their goods.

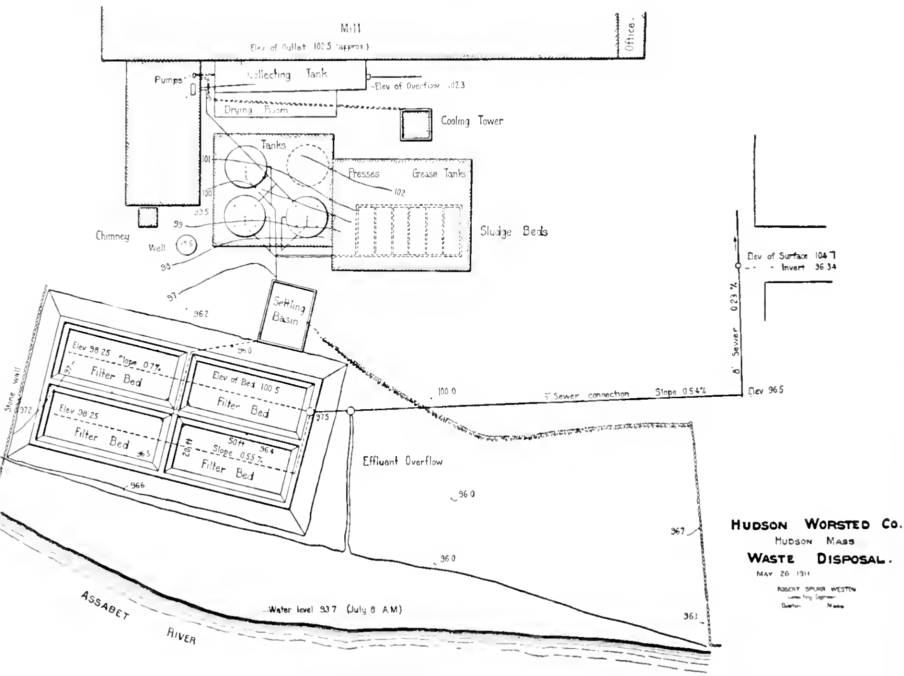
There are a great many ways of meeting the situation, but unfortunately most of the problems in this country have been studied by the manufacturer in a rather amateurish fashion. His desire must be to do the least that can be done. It is the mental attitude he naturally assumes; for he is manufacturing cloth or paper or leather; he is not running a sewage disposal plant, and for that reason cannot be expected to give especial attention to something that is a burden upon his business.

In spite of the assertions of some political economists, none of the wastes now going into sewers can ever be turned into a source of great profit; but some of the waste disposal processes can be made self-supporting.

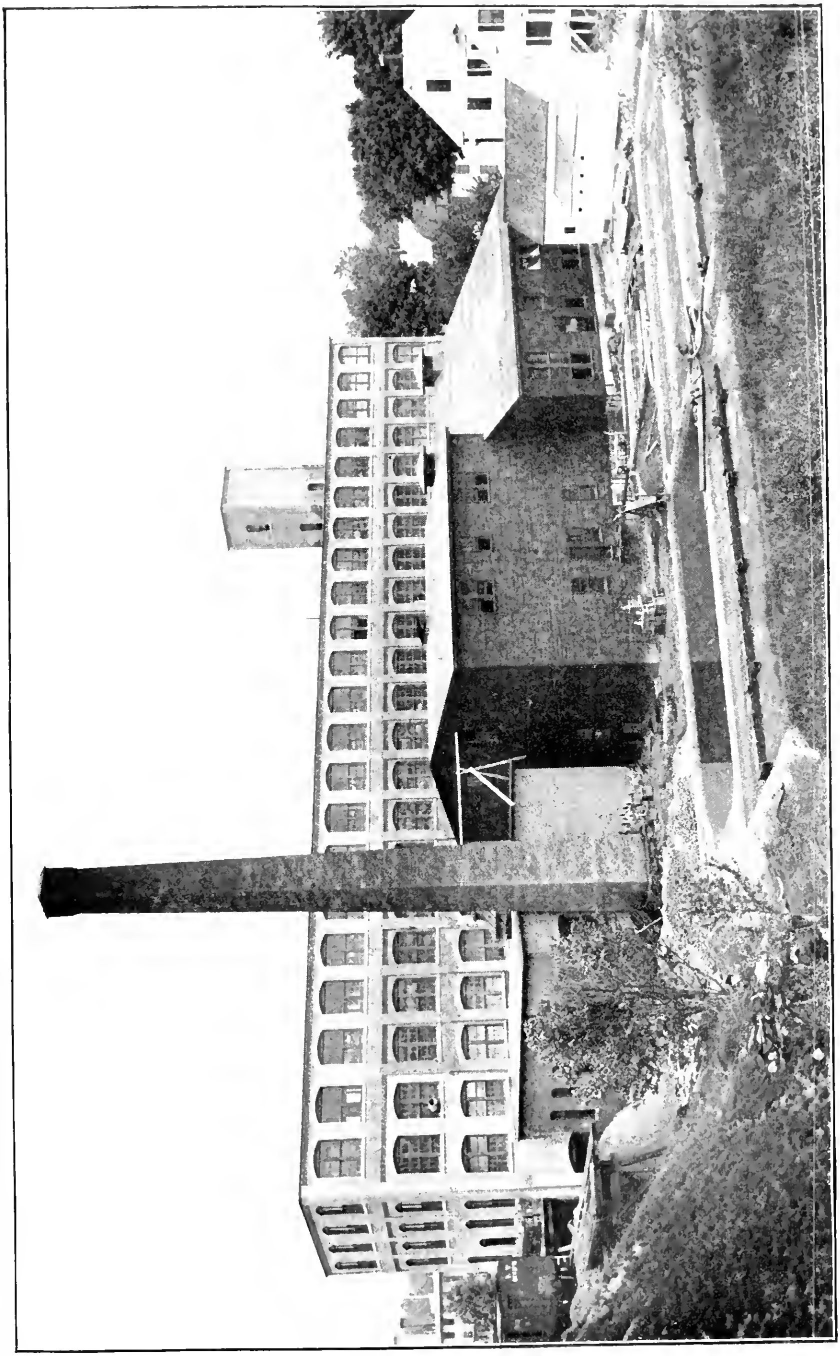
The best example is the process for recovering wool grease from water which has been used to wash or scour wool. The financial problem is not yet solved. The demand for recovered grease is limited. The price has been forced down, by the competition of a number of grease-recovering plants and a reduction in tariff, to about $1\frac{3}{4}$ cents per pound. This does not cover the cost of operating a plant of ordinary size, and it will hardly pay the cost of operation alone for plants handling half a million pounds of wool a week.

Wool waste is a very complex substance. It is the result of washing wool in water containing soap and alkali. For economical reasons this waste is necessarily concentrated, frequently containing 3 per cent. of solid matter and from 1 per cent. to 1.5 per cent. of fats. The wool itself varies greatly in character. It comes from many parts of the world and contains from 30 per cent. to 80 per cent. of impurities, which can be readily removed. It contains the so-called suint and also the true wool grease, both of which exude from the body of the animal. It also contains the dirt mechanically mixed with or entangled among the fibers. Naturally this dirt consists of the excrement of the sheep as well as particles of soil and vegetation, for example, burrs. The soil varies with the geology of the locality. It may be clay or sand. The territory wools, wools from this country, are very dirty, while the Australian wool is comparatively clean; and it often happens that

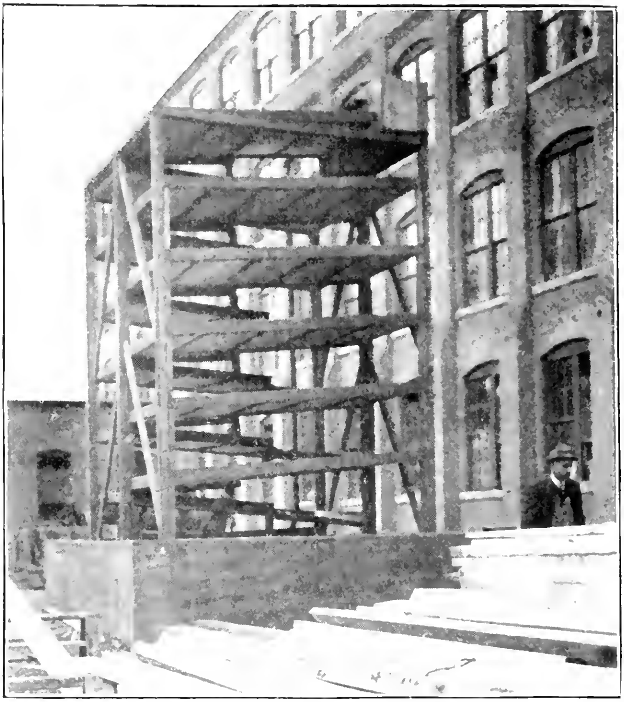
the wools which are dirtiest and require the most washing contain the least fat. Wool waste contains two valuable products, the potash salts and the true wool grease. The latter is a wax rather than a fat; that is, it will not readily saponify at ordinary temperatures with an alkali to form a soap. It readily emulsifies with water, and it is this property which makes its recovery difficult. The wool grease itself varies greatly in its melting point; and the lower the melting point, the more difficult it is to separate it from its watery emulsion. This variation is a function of the temperature, wool from the colder climates containing grease of lower melting point.



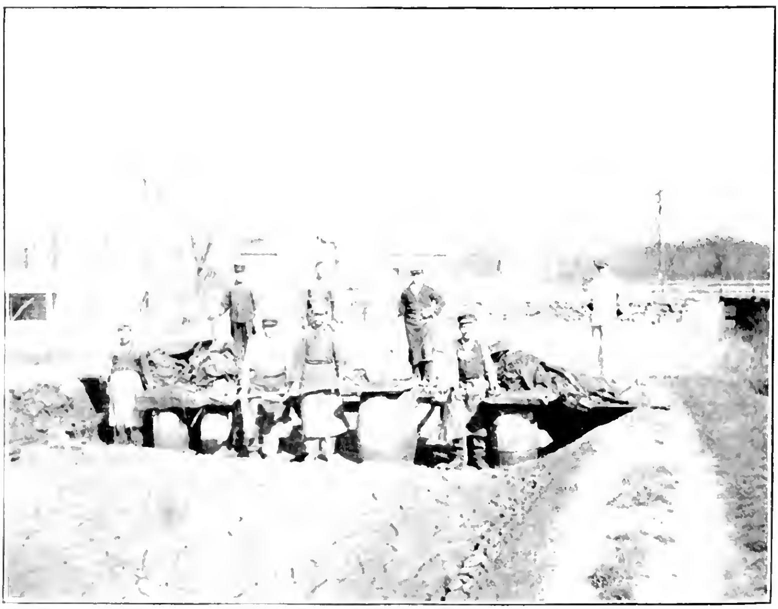
Briefly, the processes for grease recovery from wool waste may be separated into three different classes. First, the pure mechanical recovery of the grease from the suds by beating and skimming ("battage"). This process is employed in France with some degree of financial success. Second, the process of treating the waste with some acid or some acid salt, precipitating the greasy sludge from the liquor and then recovering the grease from the sludge, either by first pressing the sludge in a filter-press and then steaming out the wool grease from the



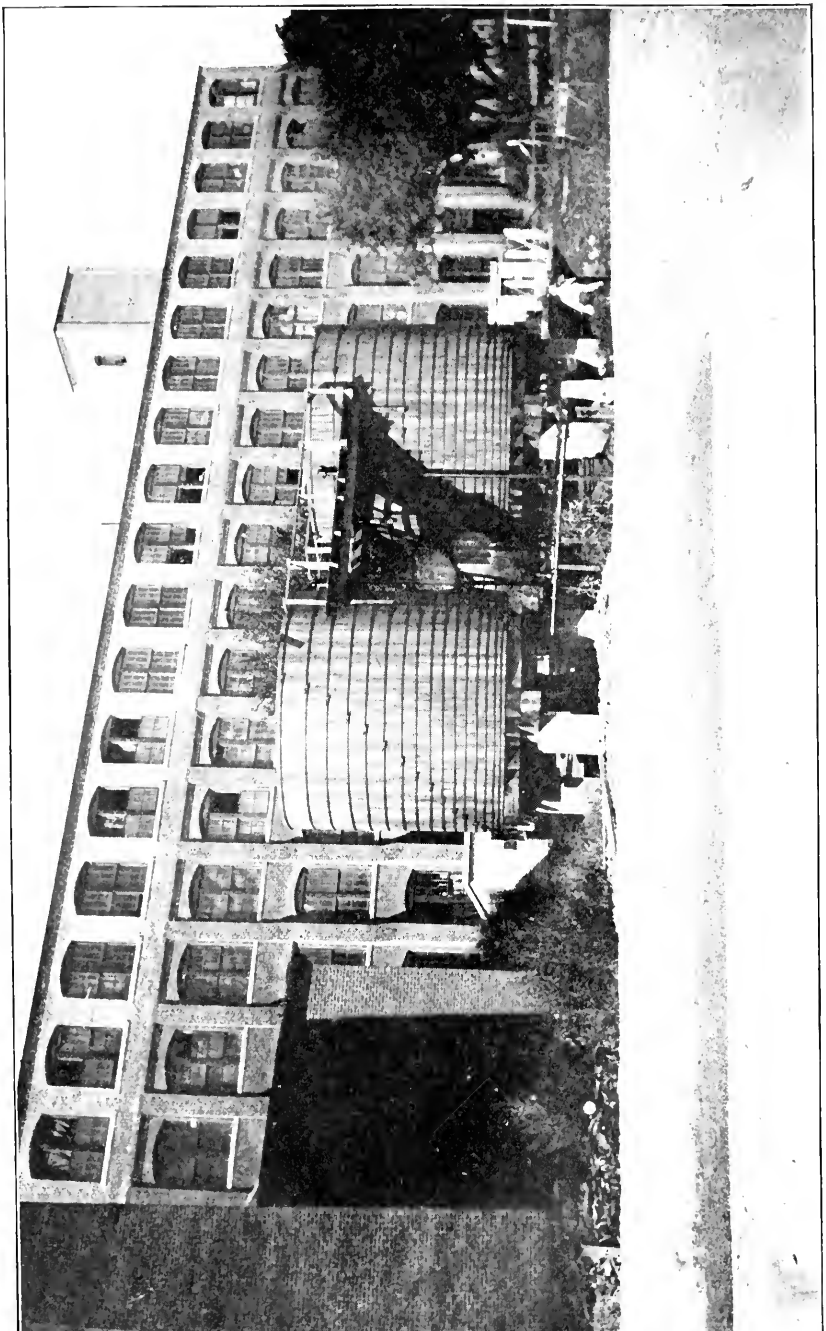
General View of Buildings and Filter Beds.



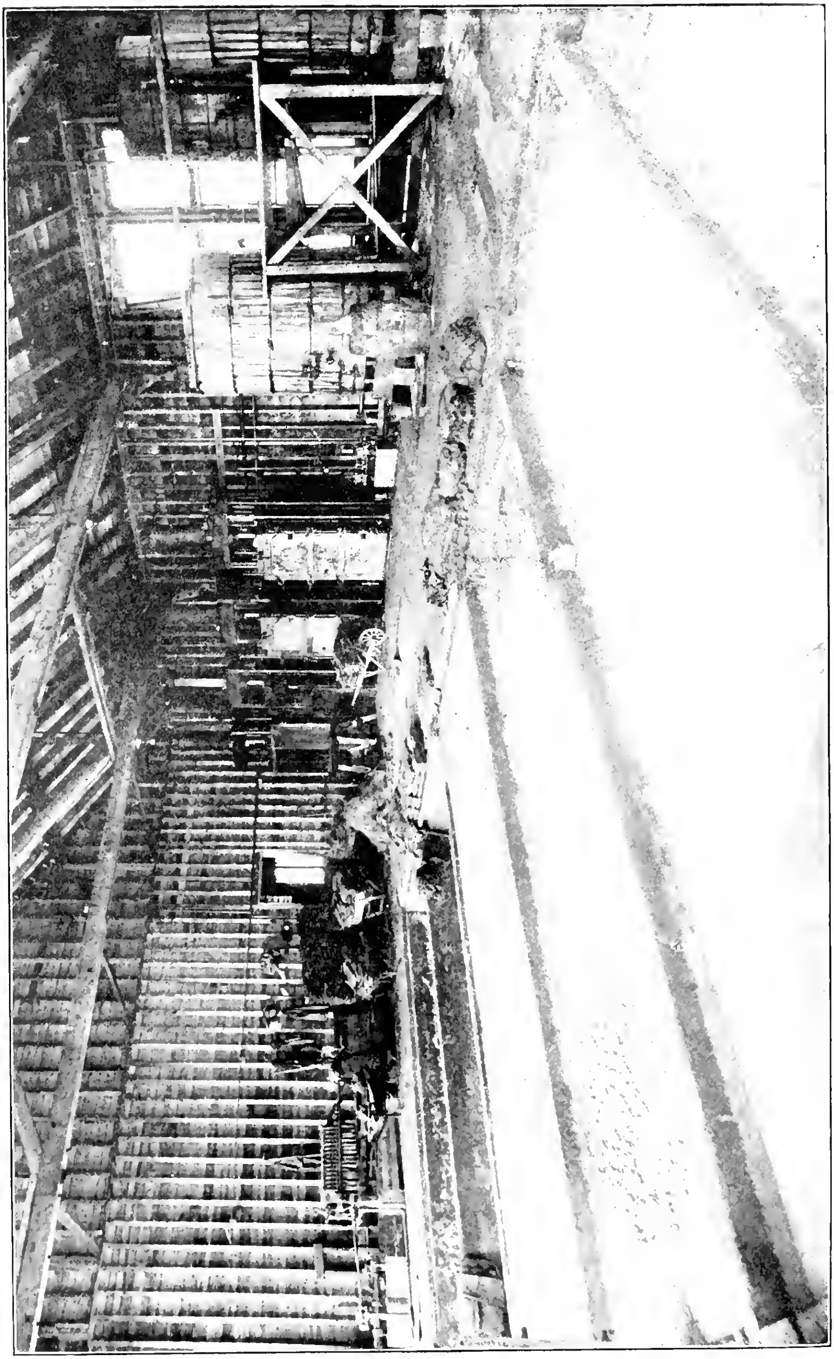
Cooling Tower for Raw Waste.



Bagging Sludge from Sludge Beds.
Sludge was emptied from settling basin and dried.



Tanks before Erection of Building over Them. Filter Beds in Foreground.



Interior of Building, showing Sludge Beds, Presses and Grease Tanks; also Bagged Sludge Ready for Pressing.

filter-press cake by means of superheated steam admitted to the press; or by drying the sludge on beds or otherwise and then forming it into cakes or "puddings" with the aid of bagging and pressing these puddings out in a hydraulic press surrounded with a steam jacket. It is this latter process that is employed at Hudson, Mass.

This consists of, first, a settling tank which receives all the wool waste from the factory. This waste is at too high a temperature at most times of the year to enable one to effect the precipitation of the grease from those wools, because the melting point of the wool fat is so low that it won't separate from the liquor after being treated with acid; so it is necessary, second, to put the waste through a cooling tower to get the temperature down to 80 degrees fahr. or below. The third step is to pump the waste into one of three treating tanks, each holding 18 000 gal. of waste. Then from 800 to 1 100 lb. of sulphuric acid is added to the 18 000 gal. of suds, and the whole mass agitated with air. After settling, the sludge separates out and the clear liquor is decanted through a settling tank discharging on the filter beds, and the effluent from the filter beds runs into the stream.

The settled sludge contains the grease. It settles out in the treating and settling tanks and on the surface of the filter beds. The practice at Hudson is to allow the settled treated waste to run through another settling tank holding about one tankful of waste. The effluent is discharged on a partially clogged filter bed and then decanted from that into a recently scraped bed. These beds are shallow, 1 000 sq. ft. in area each, and filled with about 2 ft. of cinders, covered with about 4 in. of sand and this in turn with a coating of sawdust, the sawdust serving to retain grease, which otherwise would tend to pass through the filter, and, furthermore, to show a sharp line of demarcation between the filtering layer and the sludge layer. The effluent from these beds at Hudson is discharged into the stream.

The sludge from the treating tanks is passed into sludge beds, and after several days' treatment the sludge is made into puddings by being folded into squares of wool sacking. Several layers of these sacks are placed between successive iron plates in the hydraulic press. They are then steamed and squeezed. The grease, mixed with hot water, runs out. It is then decanted. The grease, of course, rises to the top and is skimmed off, and the greasy water is put back into the tanks for retreatment. The skimmed-off grease is refined by being

boiled with steam and sulphuric acid, redecanted and barreled. This process furnishes a wool grease which contains a small percentage of water and acid and has an acrid "sheepfold" odor. It is used for stuffing leather, for making axle grease and has a few other common uses. It has a market price of something less than 2 cents a pound. Because of its odor and acidity its uses are limited.

The third process of recovering wool grease is to evaporate the alkaline suds as they come from the scouring bowls and then to separate the grease from the hot evaporated mixture by means of a centrifugal machine. This process has been used successfully in England and in Germany, but not in this country as yet. It has the advantage of producing a very much higher grade grease than that produced by the acid treatment. It is a method which requires a great deal of capital and very skilled attendants. The grease recovered by evaporating and centrifugalizing the suds fetches a price of from 4 to 5 cents a pound. The process has the additional merit that it is possible to recover a great deal of the potash from the waste water from the centrifugal machine. This, of course, is very valuable as fertilizer and brings a price of about 5 cents a pound. It is impracticable to recover the potash with the other system of treatment, such as used at Hudson.

The chief problems in connection with the treatment of wool-scouring waste by the acid method are the presence of acid, the recovery of grease from the sludge and the high labor cost. The sludge, of course, is very sticky and dries slowly. If too little acid be used, separation of sludge and liquor will not be complete; and if too much be used, the effluent will be so acid as to prevent its discharge into a stream or sewer. The labor required is a very large item; at Hudson it is over 50 per cent. of the value of the product. Calcium chloride has been suggested as a precipitant. It has been tried at Hudson with unsatisfactory results. It has also been tried in conjunction with sulphuric acid; that is, neutralizing with acid and adding calcium chloride as a precipitant. But so far this very hydroscopic salt, when mixed with sludge on the sludge beds, greatly interferes with drying and makes a slimy sludge to handle, instead of one that is of the consistency of new cheese.

The other problem in connection with getting the grease out of the sludge is, of course, a very important one. In England, and, I understand, in one place in this country, they press the sludge in a filter press and then try out the grease from the

press-cake by superheated steam. This has not been tried at Hudson as yet. Future improvement lies along these lines; that is, in doing away with hand labor, thus avoiding most of the shoveling, bagging, handling, etc., in the present methods.

For a number of years one large mill has been washing wool in naphtha, — a very light grade of gasoline, — and has been recovering neutral grease from the naphtha solution by evaporation. For a number of years this was a profitable process, but the very fact that it has been done successfully has caused the price of grease, even of this higher grade grease, to fall, and it has been rumored that for a year chemists have been working on the problem to see if they cannot find a method of refining the grease by which they can produce a grease of so much higher grade that they can afford to recover it in this way, as previously.

The plant at Hudson, since the first few weeks of uncertain management, has furnished an effluent which has been clear for over 90 per cent. of the time, and has had a color ranging from yellow to a light brown. It contains below 20 parts of fats per 100 000 and also suspended solids below the same limit. Some analyses showed 3 and some 5 parts of fat in 100 000, but these are rather lower than the average results. From the standpoint of lower riparian owners, the process is successful, but I doubt whether manufacturers would call it successful. It would be an expense to them and considerable bother. The recovery of grease in this way, with the price at less than 2 cents a pound, cannot be carried on at a profit. With the price above 2 cents there should be some return on the investment, depending on the size of the plant and upon local conditions. One is not aware how much work is being done along these lines outside of the United States. Some figures from the report on conditions in the West Riding district of Yorkshire would be of interest. Here exist large communities engaged in manufacturing, and relatively small flows in the streams. At the same time it is an example of how to preserve the appearance of the stream without hampering the growth of industry.

The West Riding district comprises an area of about 2 750 sq. miles and a population in 1905 of 2 750 000, including the cities of Sheffield (450 000), Leeds (440 000), Bradford (300 000), Halifax (105 000), and Huddersfield (95 000). In 1905 there were in this district 2 005 factories discharging waste as follows:

Kind of Industry.	Number of Factories.
Coal works	59
Leather works	143
Breweries and malt houses	247
Paper factories	26
Textile mills	960
Bleacheries	16
Iron and metal works	98
Chemical, gas and soap works	160
Stone and marble works	50
Miscellaneous	246
Total	2 005

Of these 2 005 factories, 941 discharged their waste directly into the various streams of the district, while 1 064 were connected with the city sewers and the wastes were disposed of in connection with the town sewage. Of the 941 factories discharging wastes directly into the streams, over 60 per cent. (651) were provided with purification plants, leaving only 290 from which wastes were discharged directly into the streams without purification. In other words, less than 15 per cent. of the industries in this district discharged trade wastes directly into the streams without purification.

The conditions in the United States and Canada are in great contrast to those prevailing in England. In the first place, the same necessity for purification of trade wastes has not existed except on a few streams, and on these the degree of contamination has been allowed to exceed greater limits than abroad. The common practice is to discharge into a stream or to connect with the municipal sewer and place the burden of purification upon the public.

In Peabody, Mass., where numerous tanneries discharged directly into the sewer when first built, and in several other places, serious clogging of the sewer and great outlay for cleaning have been caused. Therefore, in such cases it is not at all unlikely that the cheapest plan for all concerned, — that the municipal sewage disposal works should not attempt to dispose of more waste in connection with its domestic sewage than it can do economically, and the manufacturer should give any troublesome waste sufficient preliminary treatment to bring about this result, — will be forced into use in densely populated industrial centers in America as it has been in England, even if the city has to bear a portion of the expense of treatment at the factories.

No general method can be devised for all cases, and each problem must be handled separately with due regard both to the conditions obtaining at the factory and also to the quantity and character of the body of water into which it is proposed to discharge the purified waste.

DISCUSSION.

MR. METCALF. — I have been very much interested in these excellent descriptions by Mr. Barbour and Mr. Weston. I have had some experience along this same line and know how difficult it is to treat wool-scouring waste. There is one thing not brought out clearly in Mr. Weston's paper, and that is the fact that it is generally found advisable to get rid of the sand contained in the wash water, in the scouring liquor, as quickly as possible, and not attempt to put all of it through the process as well as the grease obtained frôm the sludge beds, of which Mr. Weston has spoken. While some grease is wasted in that way, the process is hastened very much, and the amount wasted would not be suficient to pay for the time lost. So, usually, some form of settling tank is introduced through which the sand can be drawn off.

I was a little surprised to hear Mr. Barbour set the shrinkage of wool at so low a figure as 25 to 65 per cent., or an average of about 40 per cent. In my experience, the shrinkage in American territory wool has been more often from 60 to 75 per cent., and in the Australian wools about 50 per cent., — 40 to 50 per cent., or thereabouts, — unless the wool has been washed out at some previous time, in which case, of course, you would get less shrinkage.

Mr. Weston has referred to the amount of grease contained in the different wools without giving figures, and it may be of interest to mention the fact that with territory wools, — as he has said, you get less grease, — my experience has been that with territory wools you get 8, 10 or 12 per cent. of grease, and in the case of the Australian wools, it will run from 12 to 16 per cent. So that you want to be careful to find out, if any one talks to you about the recovery of grease, whether it is being recovered from Australian wool or from American wool. If you are running your plant on the Australian wools, it may be possible to earn your fixed charges and pay something on capital account. If you are running wholly on territory wools, I question whether it is possible for you, at the present market price, or even at 3 cents a pound, to meet operating charges, much less

pay interest charges on your plant. Five or six years ago it was possible, even on territory wools, to meet expenses of operation and have a little margin to go towards fixed charges.

In this country it might also be said that the presses are usually of the type described by Mr. Weston. In England and Germany they have used another form of press, — similar to that used in sewage practice in pressing sludge, but the difficulty here, at all events so far as I have known of its trial, has been that the maintenance charges are prohibitive. The acid contained in the grease eats out the bagging very quickly. Heavy duck or drilling has been used for the press, but that lasts but a short time. One of my clients is now trying a woolen bagging to see whether it will last enough longer than the duck to justify its greater cost. I fear it will not, but it is an interesting experiment, at all events.

Mr. William S. Johnson. — In this Hudson case it was my privilege to represent that unfortunate third party mentioned by Mr. Barbour, the owner of the factory on the Assabet River at Gleasondale, below the Hudson Worsted Company and below the sewage purification works of the town of Hudson. When the unpurified wool-scouring wastes were discharged directly into the stream, the water became unfit for washing and dyeing and after vigorous protests the wastes were taken out of the stream and discharged into the Hudson sewers. For a short time there was no trouble, but soon the town filter beds became inoperative and the river received not only the unpurified wool-scouring wastes, but also the unpurified, or partially purified, sewage of the entire town of Hudson. Later on, during the period of construction of the wool-scouring plant, and before the method of operation had been determined, imperfectly purified wastes from the plant caused considerable trouble.

I have necessarily appeared so much as a critic in this case in the last three or four years that it is a great pleasure to me now to say how well it has been handled both by Mr. Weston for the Hudson Worsted Company and by Mr. Barbour for the town of Hudson. The results during the past season, in which the flow of the river has been unusually low and the effect of the pollution correspondingly increased, have been eminently satisfactory. The water of the river at my client's factory has been better than for many years past.

I am interested in another case where the conditions, unfortunately, are not so satisfactory. A wool-scouring plant has been put into operation to prevent the pollution of the water used by a paper mill on the stream below, but ever since its

construction there has been one thing or another which has caused it to give unsatisfactory results. The troubles which have been experienced at this plant have impressed upon me the frailty of such a machine, — there are so many things to get out of order and so many that require constant and skillful attention.

In the case of which I speak, after the plant was put in operation, it was left in the charge of an Italian foreman with a gang of Italian laborers to assist him. It is evident that the proper operation of such a plant with unskilled superintendence is absolutely impossible. It is a very delicate mechanism both from the chemical and from the mechanical standpoint. Neglect of any of the mechanical details or an error in the application of the acid means in each case either an imperfectly purified effluent or the discharge of the raw wastes into the stream. In order for such a plant to be successful, it must not only be properly constructed, but must be handled in an intelligent manner. In the case of the Hudson Worsted Company's plant, I understand that the operation of the plant is still under the general supervision of Mr. Weston, while in the case of the other plant referred to, there is no skilled supervision and results speak for themselves.

The effect of wool-scouring wastes on a river is in many respects quite different from the effect of house sewage. The grease in wool-scouring waste is very stable, and it is the accumulation of the grease particles on the surface of the water which causes the greatest amount of trouble. A little patch of grease forms on the water, floats down the stream, gathering to itself other particles of grease and also particles of dirt or other matter which may be in the water, and finally it has become a mass of dirt and other impurities cemented together by grease, and this combination of grease and dirt is disastrous in dyeing and many other manufacturing processes. An analysis of a sample of the water collected in the usual manner might not give any indication of the grease.

In the immediate vicinity of the point where wool-scouring wastes are discharged into a stream there is always a deposit of the heavier matters. A portion of these substances undergoes chemical changes and evolves gases, which finally, getting beneath portions of the solid matter which are matted together, have sufficient buoyancy to raise the matted material to the surface. These masses thus lifted to the surface add very materially to the pollution of the stream, especially in warm weather, when the formation of the gases is most rapid and

when a considerable portion of the material which has accumulated on the bottom during the cold weather may be carried downstream.

Mr. Barbour at the end of his paper made a few general remarks upon the advisability of allowing manufacturing wastes to enter the town sewers. This is a matter of great importance and one which is bound to interest us all more or less in the near future. In England, the Royal Commission on Sewage Disposal recommended that the law should make it the duty of the local authority to provide sewers to carry manufacturing wastes as well as domestic sewage. In this country, we have taken a stand rather the other way, and it seems to me that we are more nearly right, although there is something to be said on both sides. It seems to be a somewhat parallel case to the disposal of the dry wastes from the downtown stores which is agitating the people in Boston at the present time. The superintendent of streets has decided that the city shall not remove certain of the solid wastes from the department stores and other places, but that each store shall provide for the disposal of such wastes as a part of its business.

Sewers are constructed primarily for the purpose of removing the wastes from houses, and the householders are assessed for this purpose. When manufacturing wastes are discharged into the sewers, the cost both of the construction and maintenance of the sewers and the cost of the sewage disposal works may be enormously increased, and in that case, unless a sufficient payment is made by the manufacturers, the householders or taxpayers must be assessed to increase the manufacturers' dividends.

There is another reason why, on small streams, where there are many factories, the wastes cannot be discharged into the sewers. If such disposition were made of the liquid wastes, there would be no water left in the stream for the factories below. In the case of the factories on the Neponset River, and also upon the Nashua River at Fitchburg, the whole flow of the stream in dry weather is used over and over again in the manufacturing processes, and disposal into the sewers is out of the question.

There is no waste which cannot be purified by the manufacturers. It is only a question of expense. I believe it is possible in most cases to recover a portion at least of the expense from the wastes themselves. It may be impracticable to do this in a small way, but in the large factories it certainly can be done. We may at some time handle it as is done in some parts of England, where a company is formed to take the waste from the

factories, purify it and incidentally recover whatever is worth recovery from it. In some cases the company pays a small amount to the manufacturer for the privilege of treating his wastes. In other places, where the wastes are less valuable, the manufacturer pays the company. Where mills are near together, one company can obviously handle the product of a number of mills to much better advantage, and it saves the manufacturer from the annoyance of carrying on another industry in which he has little interest.

Mr. Metcalf. — I fully agree with what Mr. Johnson has said as to the difficulty of handling these wastes. I had a similar experience in Rhode Island, where a mill high up on the stream — it was a very small stream — had very little water at certain times for dilution of its waste. At a distance of four or five miles below there were dye works, with very good sedimentation on the stream. Under normal conditions they did not get into trouble; but during the dry season the grease accumulated in the deep pools and ponds, and then when the storms came the stream was flushed out, — the sedimentation being swept downstream and causing the dye works trouble.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1911, for publication in a subsequent number of the Journal.]

THE DESIGN OF ECCENTRICALLY LOADED CONCRETE MEMBERS REINFORCED ON ONE FACE ONLY.

By Charles H. Dutton, Member Boston Society of Civil Engineers.

[Presented to the Society, December 21, 1910.]

The following paper is intended to assist in the design of reinforced concrete structures which are stressed mainly in compression, but on account of the eccentricity of the resultant line of pressure require reinforcement on one side of the section only. There are many cases of this kind, such as retaining walls, subway arches, etc. The text-books in common use give methods of designing symmetrically reinforced members under combined direct compression and flexure, but do not cover the case of reinforcement on one side only, and, while the exact solution of the case under consideration may be effected by means of a cubic equation, the process is very laborious compared to the use of a simple table and diagram.

Let

f_s = fiber stress in the steel.

f_c = maximum stress in the concrete.

E_s = modulus of elasticity of the steel.

E_c = modulus of elasticity of the concrete.

$n = \frac{E_s}{E_c} = 15.$

d = distance from center of steel to compressive face of the concrete.

b = breadth of the member.

kd = distance from the compressive face of concrete to the neutral axis.

N = the axial stress.

e = distance from a point midway between the steel and the compressive face to line of the axial stress.

p = the ratio of area of steel to that of concrete.

By the straight line theory —

$$f_s = nf_c \cdot \frac{1-k}{k}. \qquad (1)$$

Σ parallel forces:

$$N + f_s bdp = \frac{kd}{2} f_c b. \qquad (2)$$

Moments about the centroid of compression:

$$N\left(e-\frac{d}{2}+\frac{kd}{3}\right) = f_s bdp\left(d-\frac{kd}{3}\right). \qquad (3)$$

Solving equations (1), (2) and (3) simultaneously, since the member is in equilibrium, —

$$p = \frac{k}{4n\ (1-k)}\left[\frac{N}{ef_cb}+2k-\sqrt{\frac{N}{ef_cb}\left[\frac{N}{ef_cb}+8k\left(1-\frac{k}{3}\right)\right]}\right]. \qquad (4)$$

$$d = \frac{4e}{-1+\sqrt{1+\dfrac{8k\left(1-\frac{k}{3}\right)}{\left(\frac{N}{ef_cb}\right)}}}. \qquad (5)$$

Since equation (4) is solved from a quadratic, it requires a plus sign before the radical. It is omitted, as it gives negative value of d. Equations (4) and (5) are for the numerical solution of the problem, the value of k being obtained from equation (1) by assuming values of f_c and f_s.

As the numerical solution is somewhat laborious, the following solution by means of a diagram will be found convenient.

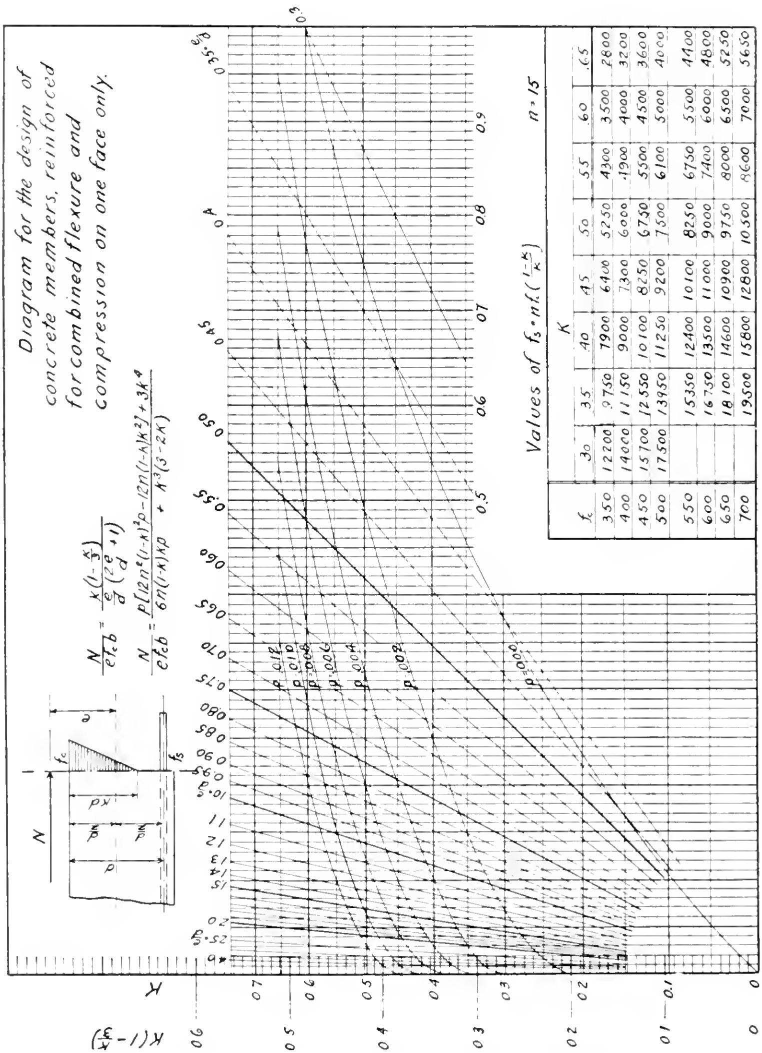
Transposing equations (4) and (5) respectively:

$$\frac{N}{ef_cb} = \frac{p\ [12n^2\ (1-k)^2\ p-12n\ (1-k)k^2]+3k^4}{6n\ (1-k)\ kp+k^3\ (3-2k)}. \qquad (4a)$$

$$k\left(1-\frac{k}{3}\right) = \left(\frac{N}{ef_cb}\right)\left[\frac{e}{d}\left(\frac{2e}{d}+1\right)\right]. \qquad (5a)$$

On the diagram $\frac{N}{ef_cb}$ is the independent variable or abscissa; k or $k\left(1-\frac{k}{3}\right)$ is the dependent variable or ordinate, and p and $\frac{e}{d}$ are constants. When computing the diagram from equation (5a) use $k\left(1-\frac{k}{3}\right)$ as the independent variable. If the values of $k\left(1-\frac{k}{3}\right)$ are plotted instead of the values of k, equation (5a) reduces to an equation of the first degree in k, and therefore plots as straight lines. Thus a single point on the diagram represents four quantities, viz, — $\frac{N}{ef_cb}$, k, p and $\frac{e}{d}$. The table represents k, f_c and f_s.

If f_c and f_s are taken as constants, k becomes a constant, thereby much simplifying the problem.



f_c	K .30	.35	.40	.45	.50	.55	.60	.65
350	12200	9750	7900	6400	5250	4300	3500	2800
400	14000	11150	9000	7300	6000	4900	4000	3200
450	15700	12550	10100	8250	6750	5500	4500	3600
500	17500	13950	11250	9200	7500	6100	5000	4000
550		15350	12400	10100	8250	6750	5500	4400
600		16750	13500	11000	9000	7400	6000	4800
650		18100	14600	10900	9750	8000	6500	5250
700		19500	15800	12800	10500	8600	7000	5650

The diagram may be equally well applied in determining the stresses in a structure of known proportions, or in designing a structure to resist definite external forces without exceeding certain limiting stresses. In the former case, p and $\frac{e}{d}$ are known, and by locating the intersection of the straight diagonal line

corresponding to $\frac{e}{d}$ with the proper curve for p, we read at once the value of $\frac{N}{ef_cb}$, of which f_c is the only unknown quantity. Having obtained this, f_s may be obtained by taking k from the diagram and using k and f_c in the table.

In the other case, namely, to design a structure with definite limiting stresses, we may calculate the value of $\frac{N}{ef_cb}$ and may obtain k from the table to suit the values of f_c and f_s. With $\frac{N}{ef_cb}$ and k, the diagram will show the value of $\frac{e}{d}$, from which the necessary d may be obtained, and of p, from which, knowing b and d, the area of steel may be determined.

It is of course assumed in any case that the external forces are known. These are represented by the resultant thrust N and the eccentricity of the thrust e. That is to say, the moment may be made equal to Ne, and e determined by this means. In case the stresses are determined graphically, both the N and the e may be taken directly from the equilibrium polygon.

It is also possible to assume $\frac{N}{ef_cb}$ and d, and compute p and f; or *vice versa*. In the above work the eccentricity has been denoted by e, the distance from a point midway between the steel and the compressive face, to the line of force, N, which is perhaps the most useful method in connection with the design of arches, as the value of e changes but slightly with varying values of d.

It will of course be recognized that the above analysis is only one of several possible methods of reaching the desired solution and it may often be more convenient, when designing new work, to use some other. The question as to which is more desirable depends upon the allowable method of varying the strength. If the thickness of the wall is determined in advance, d is practically determined and consequently e, by settling the amount of cover for the reinforcement and thus locating the center between the reinforcement and the compression face.

It may be, however, that we wish to leave the thickness to be determined later, and the distance from the resultant line of pressure to the face of the wall, rather than to the center, is the condition fixed by circumstances. A familiar instance of this is in the case of a wall, such as the spandrel wall of an

arch carrying an overhanging sidewalk. Here a different diagram might be more convenient.

Under other circumstances, it might be that the distance from the resultant pressure to the center of the reinforcement is determined in advance and that the location of the compression face is immaterial. Under these circumstances the value $e + \frac{d}{2}$ is the constant, and the formulas might be modified by substituting a value, as $i - \frac{d}{2}$, for e. This results in simplifying the equations to some extent, as several terms are canceled. It will be found, however, that a similar diagram will be the most convenient way of using these equations.

Generally speaking, however, it is possible to use the accompanying diagram, as the thickness of the wall can generally be assumed with sufficient accuracy, or obtained by one trial assumption.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1911, for publication in a subsequent number of the JOURNAL.]

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVII. SEPTEMBER, 1911. NO. 3.

NEW YORK STATE BARGE CANAL.

BY WILLIAM B. LANDRETH,* MEMBER AMERICAN SOCIETY OF CIVIL ENGINEERS.

[Read before Sanitary Section of the Boston Society of Civil Engineers, December 7, 1910.]

ATTEMPTS to improve the methods of inland transportation by water on this continent date from early in the eighteenth century, when the priests of the Catholic Church began to build a canal around the rapids in the St. Lawrence River near Montreal, Canada.

The first canal in the United States was built in Orange County, New York, by the Surveyor-General for transporting stone. During the eighteenth century, and in fact since that time, there has been a great difference of opinion as to the utility and advisability of constructing canals in various parts of the United States.

When the matter of building a canal from Albany to Buffalo was seriously contemplated in the latter part of the eighteenth century, Thomas Jefferson said that it was madness to attempt the building of a canal from Albany to Buffalo, while Madison thought that the cost would exceed the resources of the entire United States and refused national aid to the project. On the other hand, George Washington was a strong advocate of the construction of a canal across New York state, and early in the

* Special Deputy State Engineer of New York, 1909–1910.

agitation of the project made a trip from Albany by way of the Hudson River, Mohawk River, Wood Creek, Oneida Lake, Oneida and Seneca rivers to Seneca Lake, and stated on his return that he hoped that the people of the state of New York would not fail to improve the great natural water courses in that state.

About 1791 first attempts were made to improve the inland navigation of New York state by the construction of locks and connecting canals by private companies.

About 1808 was inaugurated the policy of constructing canals in New York state under state aid.

The original Erie Canal had a bottom width of 28 ft. and depth of water of 4 ft. These dimensions were successively increased to a bottom width of the Erie Canal of 52½ ft. and a minimum depth of 7 ft. of water. These dimensions ruled for the Erie Canal until the inauguration of what is known as "The Barge Canal," where the governing dimensions are in land line 75 ft. on the bottom in earth, 94 ft. in rock, with river section varying from 150 ft. to 200 ft., all with a minimum depth of 12 ft. As necessarily following in the enlargement of the canals, the tonnage of the boats increased from thirty tons for the first canal to eighteen hundred tons for the Barge Canal. The dimensions of the locks increased correspondingly with the increase of section.

Construction of the Erie Canal began on July 4, 1817, and was completed October 26, 1825. The actual cost of the original canal was a little more than $7 000 000. The first enlargement was begun in August, 1836, and completed September 1, 1862, at a cost of $31 834 000. Various branch canals, such as the Champlain, Oswego, Cayuga and Seneca, Chemung Creek, Lake Chenango, Black River and Genesee Valley were built while the first enlargement of the Erie Canal was being carried out.

During the years from 1896 to 1908, a partial enlargement of portions of the various canals was made under what is known as "The Nine Million" appropriation, that amount being fixed by a Constitutional Convention when the state constitution was revised.

From 1899 to 1903 preliminary surveys, considerations and discussions of the Barge Canal took place, and in 1904 the actual preparation of final plans began.

On March 8, 1899, a committee was appointed by Governor Roosevelt to advise as to the future canal policy for the state.

The report of this committee on January 15, 1900, showed a very exhaustive study of the whole question and was accompanied by many maps and tables, records of public hearings and much correspondence with those who were qualified to advise on the subject. The committee most emphatically recommended that the Erie, Champlain and Oswego canals should be enlarged, the Erie Canal to have 12 ft. of water, the Champlain and Oswego canals 9 ft.

On April 12, 1900, the state legislature directed the state engineer to cause surveys, plans and estimates to be made for improving the Erie, Champlain and Oswego canals as recommended by the Committee on Canals, except that an alternative project was used for enlarging the Oswego to the same size as proposed for the Erie. The sum of $200 000 was appropriated for doing this work and a large force was immediately placed in the field and careful topographic surveys and borings made. Preliminary plans and estimates were completed in time to report to the governor on February 21, 1901.

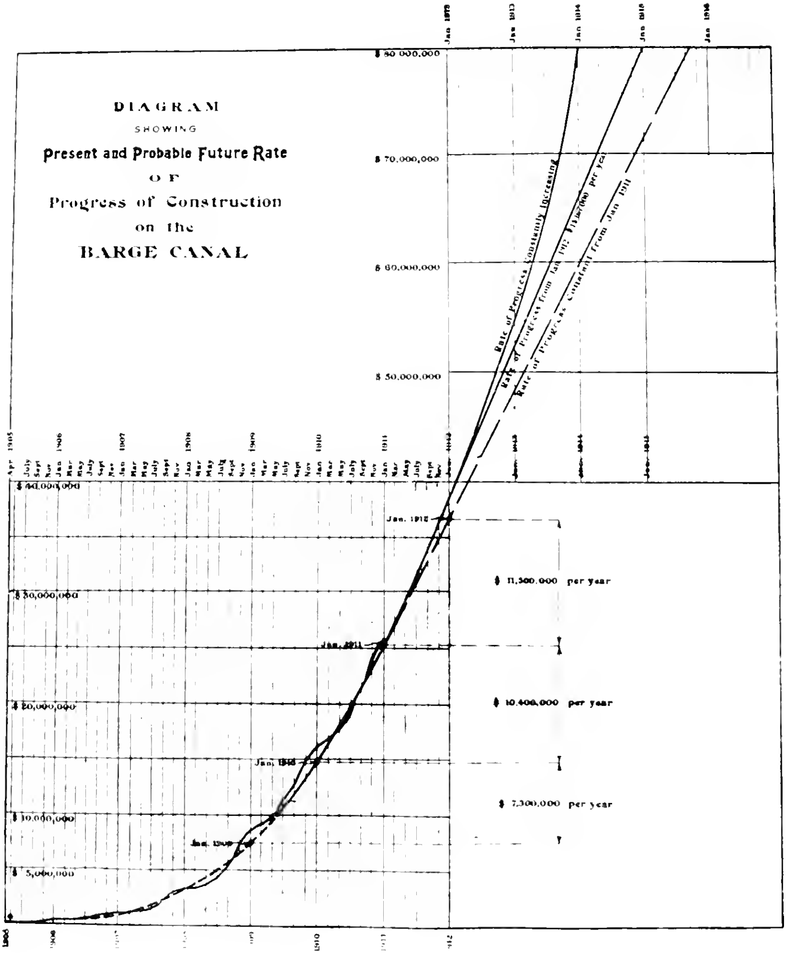
Much discussion was had in this matter in the public press, and this agitation undoubtedly resulted in the passage of what is known as "The Barge Canal Law," providing for an appropriation of $101 000 000 for the purpose of rebuilding the Erie, Oswego and Champlain canals, providing for a depth of water on all of them of 12 ft. This act was submitted to the voters in the general election of 1903, and approved by them by a substantial majority.

Contracts were entered into in April and May, 1905, and operations were speedily begun. The first actual work of construction upon the whole project was performed on April 24, 1905, at Fort Miller, on the Champlain canal; the first work upon Erie Canal at Waterford on June 7, 1905.

An important amendment to the original law was made in 1905, providing for a width of lock chamber of 45 ft. in place of the 28 ft. provided for in the original law.

The following table gives the progress of the preparations of plans and actual construction to December 1, 1910. At this date plans have been completed and approved by the Canal Board for all of the work on the Erie, Oswego and Champlain canals, with the exception of the crossing of Oak Orchard Creek at Medina, harbors at Syracuse and Rochester, and for contracts for operating machinery which will be required when the locks are completed. All of the work for which plans have been completed is under contract, except six contracts for which bids will be opened on the 24th of this month.

	Length in Miles.	Estimated Cost.
Work let	386.4	$67 551 000
Plans completed	27.3	6 874 000
Total	413.7	$74 425 000
Work done		$25 168 000



ROUTE OF BARGE CANAL.

The Barge Canal, as well as its predecessor, the Erie Canal, connects Lake Erie with the Hudson River, the Erie Canal entering that river at Troy and the Barge Canal at Waterford. From Waterford westward to the vincinity of Utica the Barge Canal utilizes and canalizes the Mohawk River, then passes

over a divide and into Oneida Lake, and through Oneida Lake and Oneida River to Three River Point, the junction of the Oneida and Seneca rivers. It then ascends the Seneca River and its branches to Lyons. From Lyons to the Genesee River at Rochester the canal follows generally in the valleys, and is really a land line. Crossing the Genesee River at Rochester in a pool formed by a dam, the canal westward to Lockport is a virtual enlargement of the existing Erie Canal. From Lockport to Tonawanda, the canal follows the route of the Erie Canal and Tonawanda Creek canalized. From Tonawanda to Buffalo and Lake Erie, Barge Canal traffic will pass through the Niagara River.

The Oswego Canal starts at the junction of the Oneida, Seneca and Oswego rivers, passes northward in the Oswego River to Lake Ontario.

The Champlain Canal, starting at Waterford in the Hudson River, follows that river to Fort Edward, then passes across a divide to Fort Ann, then through Wood Creek canalized to Lake Champlain at Whitehall.

Starting at the Niagara River at elevation 565.6, the Erie Canal descends by various locks to Three River Point at the junction of the Oneida, Seneca and Oswego rivers. Proceeding eastward the canal ascends to the Summit Level at Rome at elevation 420 and then descends eastward in the Mohawk valley to elevation 184 above the Cohoes Falls; then to elevation 15.2 in the Hudson River at Waterford.

The Oswego Canal descends northward from Three River Point at elevation 362 to Lake Ontario at elevation 244.4.

From Waterford the Champlain Canal ascends to elevation 140.0 near Fort Edward; then descends northward to elevation 96.5 at Lake Champlain.

Water Supply — Erie Canal.

That portion of the canal from Tonawanda eastward to Three River Point will be supplied by water mainly from the Niagara River, supplemented by additional supplies from a series of lakes known as the "Finger Lakes," tributary to the Seneca River. The Summit Level at Rome will be supplied from existing reservoirs south of the Erie Canal between Syracuse and Rome, and from storage reservoirs on the Mohawk River at Delta, and on West Canada Creek at Hinckley. Water from the latter reservoir will be carried down West Canada Creek for a few m

and then by a new open channel across a divide into Nine Mile Creek, a tributary of the Summit Level.

The Summit Level of the Champlain Canal at Fort Edward will be supplied from an existing feeder taking water from the Hudson River at Glens Falls.

The reservoirs at Hinckley and Delta have the following dimensions:

Hinckley Reservoir.

Capacity — 24 768 600 000 gal.
Area of watershed — 372 sq. miles.
Area of reservoir — 4.46 sq. miles.
Height of dam from lowest point of foundation to crest — 90 ft.
Maximum depth of water at dam — 75 ft.
Average depth of reservoir — 36 ft.

Delta Reservoir.

Capacity — 20 570 000 000 gal.
Area of watershed — 137 sq. miles.
Area of reservoir — 4.33 sq. miles.
Height of dam from lowest point of foundation to crest — 100 ft.
Maximum depth of water at dam — 70 ft.
Average depth of reservoir — 23 ft.

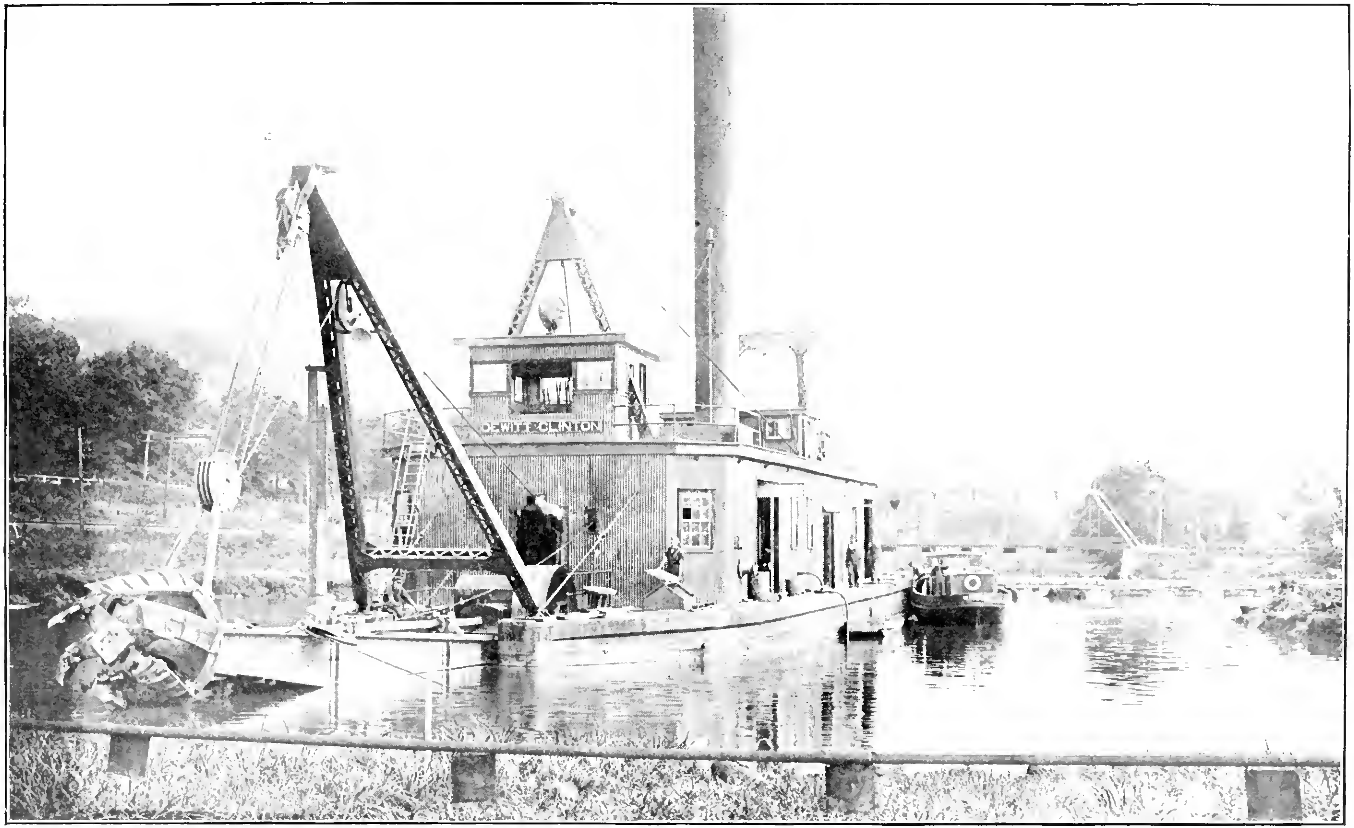
Excavation.

The total amount of excavation for the construction of the canal is estimated at 90 000 000 yd., of which about 10 per cent. is rock.

Many and varied types of excavating machinery are used on the various contracts. The stripping of embankment areas and other light excavation has been done on some contracts by the use of graders propelled by sixteen to twenty horses. Various types of drag scrapers operated either from stationary towers or revolving derricks are used. The maximum height of tower for this purpose is 90 ft.

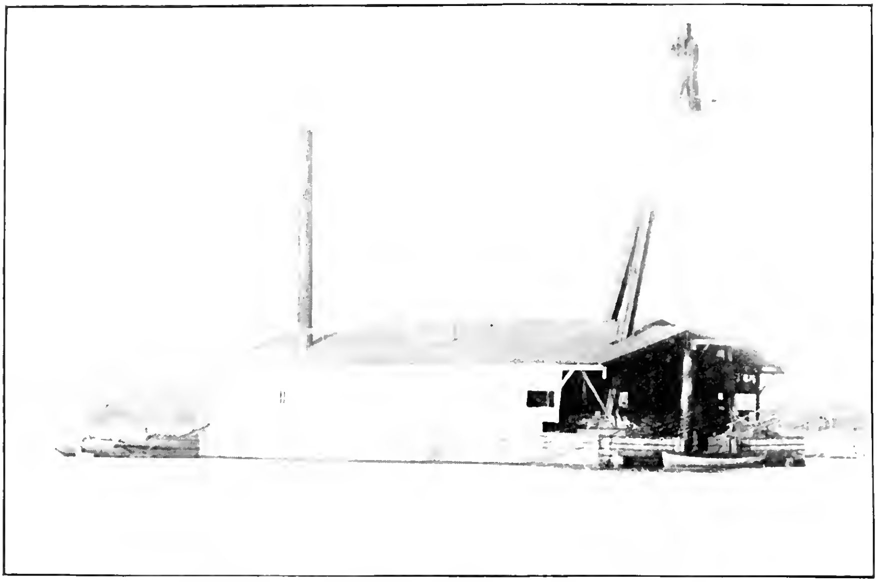
Steam shovels of varying weights and capacities with their necessary equipment of locomotives and cars are in use. In drilling the rock, common forms of steam or compressed air drill are in general use, although on certain contracts well drills cutting holes varying in diameter from $2\frac{1}{2}$ in. to 4 in. have been successfully operated.

On Contract No. 1 in the Hudson River the rock consists of shale and is broken by a Lobnitz rock-breaking machine. This consists of a steel hammer 20 in. in diameter, 16 ft. long,



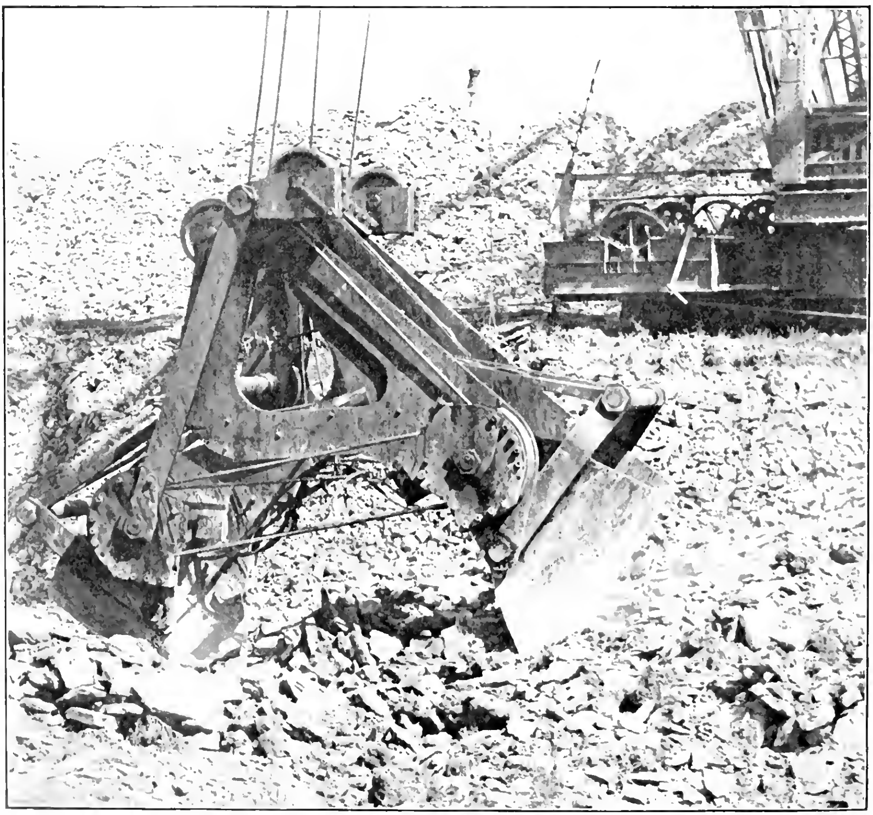
NEW YORK STATE BARGE CANAL.

Hydraulic Dredge, showing Cutter.



New York State Barge Canal. Contract No. 1.

Lobnitz Rock Breaker, Hudson River.



New York State Barge Canal. Contract No. 6.

Bucket of Grab Machine.

weighing about 16 tons. The hammer and the necessary machinery, boilers, etc., are carried on a large scow held in position by guy lines to anchors or objects on shore. The hammer is suspended by a steel cable passing over a sheave attached to the drum of a hoisting engine.

The operation of the rock breaker is as follows: The cables are fastened to trees on shore, and the hammer brought over the ledge of rock to be attacked. The hammer is lifted about 6 ft. and allowed to fall, the operation being repeated until the rock at the bottom is presumably shattered. The boat is then moved from two to four feet and another hole drilled, it being assumed that the rock between the two holes is so shattered that it can be easily removed by a dipper dredge.

Hydraulic dredges are in use at various points on the canals; among others, on the Champlain Canal, Wood Creek, the Hudson River, Seneca, Oneida and Clyde rivers, at the east end of Oneida Lake, and in Tonawanda Creek.

Most of the dredges have suction pipes 20 in. in diameter. The largest output of any dredge is 500 000 yd. in one month, working three eight-hour shifts daily.

The dipper dredges used vary in size and power, depending on the nature of the material to be removed. At the west end of Oneida Lake and various points between Rochester and Lockport, ladder dredges are in use, in which the excavated material brought up by the buckets is deposited on belt conveyors and thus carried ashore.

On Contract No. 12 at the west end of Lake Oneida, the material is deposited 165 ft. from the end of the dredge proper.

On Contract No. 6 at Rochester, a depth of from 20 to 35 ft. of limestone and shale rock is encountered. By reason of the depth of cut and the elevation of the spoil, the machine used must be able to lift its load of broken rock for a height of from 70 to 80 ft. from the bottom of the cut free and clear of all intervening machinery or obstructions and carry it rapidly to either bank as needed. For this purpose a conveyor consisting essentially of a cantilever bridge mounted on two towers 188 ft. apart is used. The framework of the bridge is of an ordinary type supported by two towers 90 ft. high. Each tower rests on a 60-ft. rigid wheel base made of steel girders which run on the axles of thirty-two standard car wheels. The car wheels run on standard-gage tracks laid parallel to the sides of the canal.

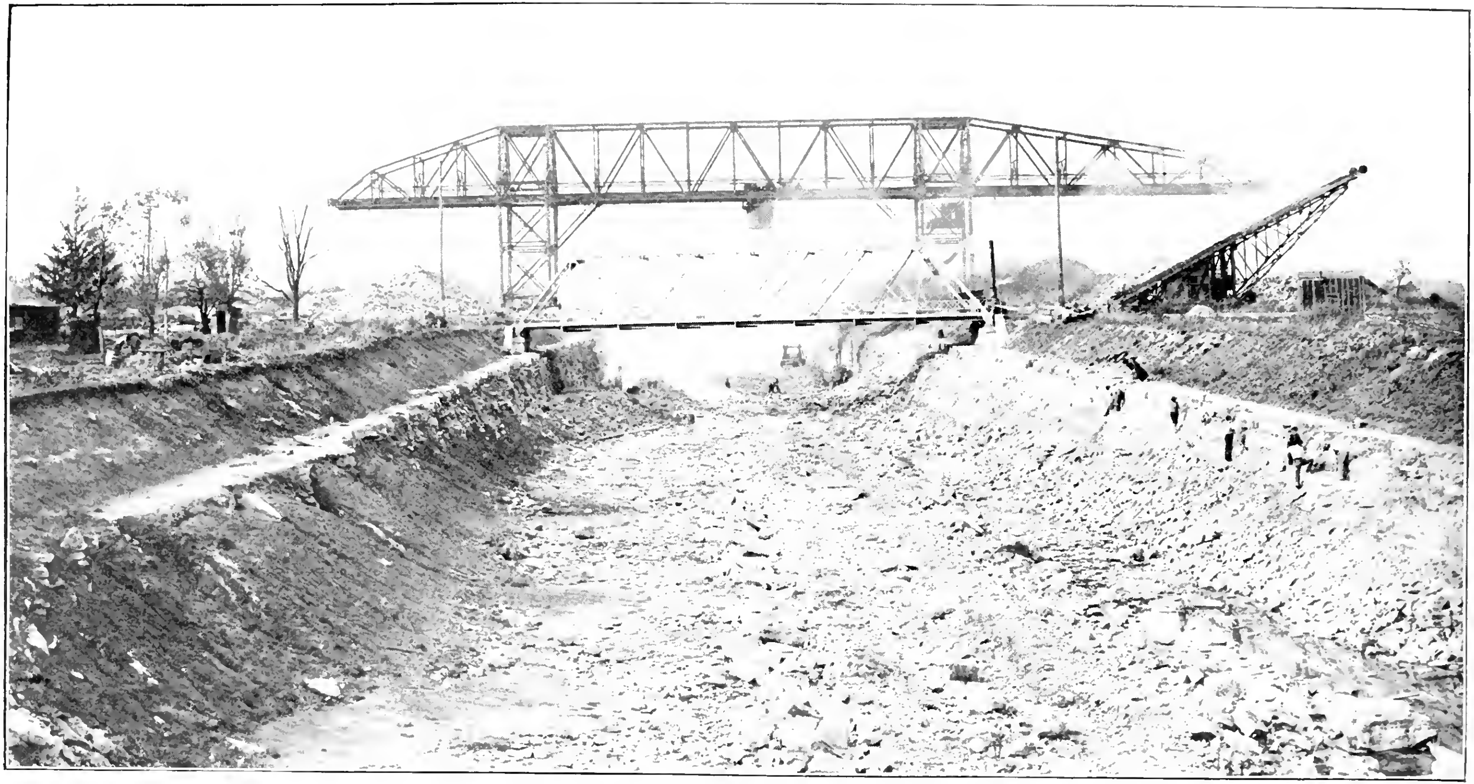
For the removal of the loosened material a bucket known as a "grab" bucket is used. The hinged bucket being loaded

is hoisted by cables and attached to a trolley running on the lower chord of the bridge. The material is deposited in spoil banks on either side of the canal. From one and one-half to two minutes is required for a round trip of the bucket. The jaws of the bucket, when opened, cover a space 20 ft. long and 10 ft. wide, and when closed have a capacity of about 8 cu. yd.

On contract No. 40, west of Lockport, a cantilever crane mounted on a single tower running on the canal bank is used. The crane has the following dimensions: Length over all, 382 ft.; total trolley travel, 366 ft.; height from base of rail to top of cantilever, 68 ft. The total reach of cantilever from end to end is 428 ft.; the extreme height, 92 ft.

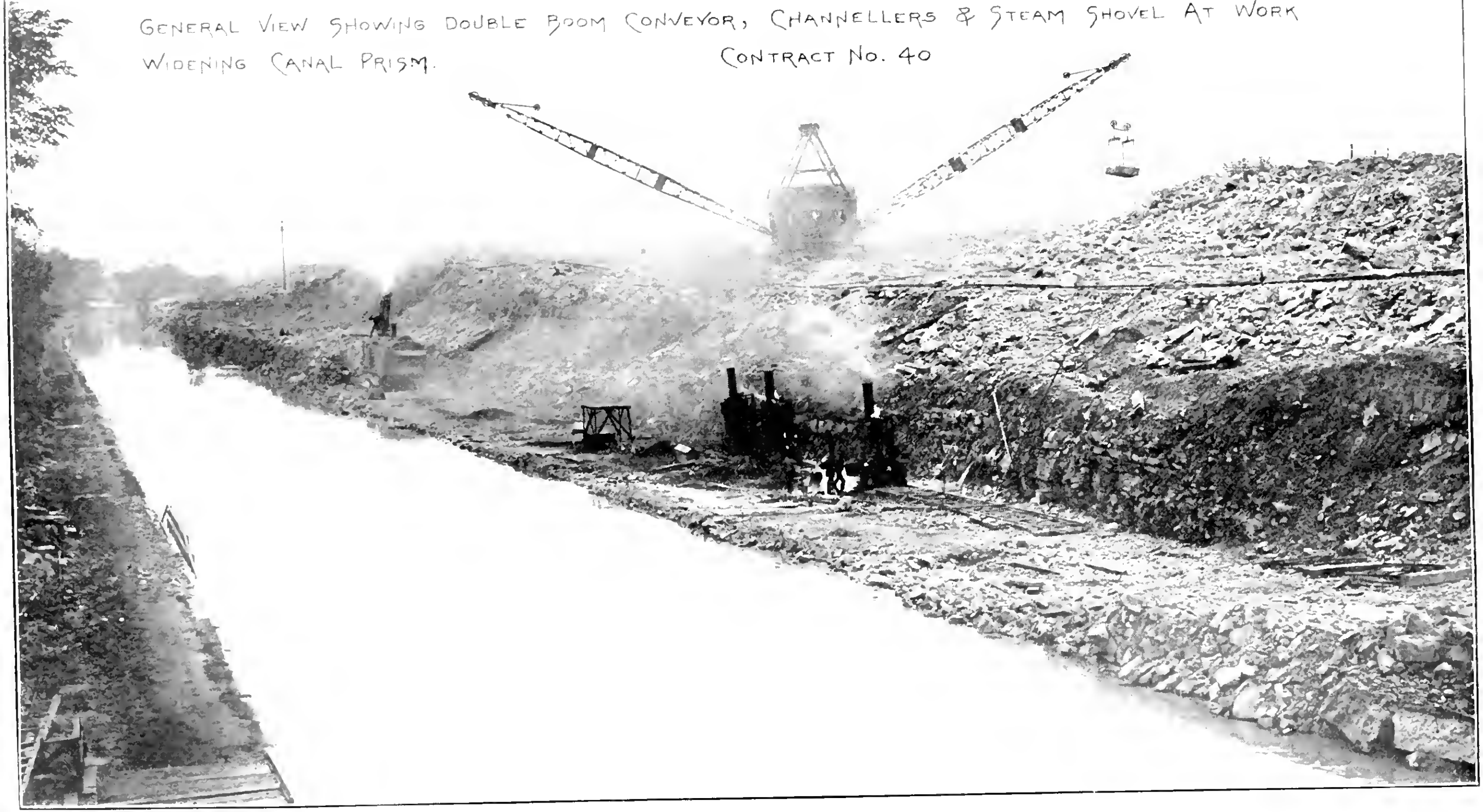
A Brown-Hoist automatic dumping shovel bucket is operated from the cantilever and the material excavated is deposited on the adjacent spoil banks without any interference with traffic passing in the canal. The maximum monthly output for this machine working three eight-hour shifts daily has been 55 000 cu. yd.

On another portion of this contract a double-boom excavator was placed in service about a year ago. This machine is operated with a 5-yd. skip on each boom and has the skip bails so arranged that it is not necessary to unhook the skips in order to load them. The machine weighs about 150 tons and has two 100 ft. booms which, when elevated at an angle of about $28\frac{1}{2}$ degrees to the horizontal, have their tip ends at a horizontal distance of about 100 ft. from the center of the machine so that the reach is practically 200 ft. It is designed to lift and carry a load of 10 tons, including the weight of the skip, on each boom, simultaneously, or to operate a $3\frac{1}{2}$-yd. drag scraper bucket on one boom. The machine is mounted on skids and rollers and is moved along the canal by throwing the drag bucket forward, getting a firm bite and pulling on the drag line. The machine was designed to make thirty complete revolutions in an hour, which would mean the loading and discharging of one 5-yd. skip every minute. In practice, due to the natural limitations of the steam shovel work, this rate cannot be attained, as the shovel cannot equal the capacity of the excavator. In the mixture of earth and rock, the best record thus far has been about 24 000 cu. yd. in thirty-two eight-hour shifts. Three men are required for the operation of the machine, one to control each of the boom engines and the third to run the rotating engine. Five other men are required to advance the track for the machine, and one man is placed in the canal prism to signal the operators.



New York State Barge Canal. Contract No. 6.

Excavation of Prism by Grab Machine and Channelers. Spoil conveyed to Bank by Aid of Tipple Conveyor. Buffalo Road Bridge in Foreground.



New York State Barge Canal

General View Showing Double Boom Conveyor, Channellers & Steam Shovel At Work Widening Canal Prism.

Contract No. 40

The machine is operated by compressed air received from a central plant, with a pressure of 80 lb. to the sq. in. at the machine.

Structures.

Many methods of mixing and transporting concrete are in use. On several contracts the gravity Haines mixer is used, while on others, various types of mechanical mixers are in operation. The concrete is transported and deposited generally in buckets running on narrow-gage cars, or by boom derricks.

On Contract No. 11 the ingredients for concrete are raised to the top of a Haines mixer by means of belt conveyors and the mixed concrete is conveyed from the mixer a maximum distance of 817 ft. over a succession of belt conveyors. On arriving at the end of the belt conveyor, the concrete is placed in the forms by lateral belt conveyors or through pipes.

On Barge Canal masonry structures, Portland cement concrete only is used. The proportions of the ingredients of the concrete are as follows:

First-class concrete — 1 part cement, 2 parts sand and 4 parts crushed stone.

Second-class concrete — 1 part of Portland cement, $2\frac{1}{2}$ parts of clean sand or crusher dust, and 5 parts of crushed stone or gravel.

Third-class concrete — 1 part Portland cement, 3 parts clean sand or crusher dust, and 6 parts of crushed stone or gravel. All of the ingredients are measured in loose bulk.

The tests for tensile strength of Portland cement, for a mixture of 3 parts by weight of crushed quartz and 1 part by weight of Portland cement are as follows:

At the end of 7 days, at least 150 lb. per sq. in.; at the end of 28 days, at least 240 lb. per sq. in. The separate samples must show an increase of strength in the 28-day test over the results secured in the 7-day test.

Locks.

The Barge Canal locks have lock chambers 45 ft. wide, a usable length of chamber of 310 ft. and a minimum depth of water of 12 ft. All of the locks but one are to have mitered swing gates, the exception being the lower gate of the lock at Little Falls, which has a solid lift gate.

A large majority of the locks have lifts from 16 to 20 ft. The five locks at the Waterford flight of locks have lifts of 34.5

ft. each, and the Little Falls lock a lift of 40.5 ft. The locks at Waterford exceed in lift any existing mitered gate locks in the world. The chambers of the locks are filled and emptied through ports in the side walls connecting with the conduits, and the flow is governed by vertical lift valves, with the exception of one lock at Oswego, where the chamber is filled and emptied by siphons.

The siphon lock at Oswego, designed by Mr. D. A. Watt, M. Am. Soc. C. E., supervising engineer, is modeled generally after similar locks in use on the Elbe Canal in Germany.

In these locks the culverts are built with siphons, but the lock gates are operated by an ordinary mechanical device. Briefly described, the operating principle comprises a culvert in each wall, the portion near each end being turned up to form a closed siphon. The crown of each siphon communicates by means of pipes with a tank placed high in the wall, arrangements being made to fill the tank from the upper pool when required, as well as to empty it into the lower pool. After the tank has been filled it is shut off from connection with the upper pool and with the outer air, and the emptying valve is then opened. This has the effect of suspending the water in the tank, so to speak, and thus creating a tendency to vacuum. On connecting a siphon with the tank, the air is drawn out of the former and the water rises over the crest and soon fills the neck. When it runs full it reverses the draft and draws the air back from the tank and carries it out with the flow, filling the tank again and restoring the vacuum automatically. The flow in the siphon can be checked or stopped at any moment by opening a small valve communicating with the outer air.

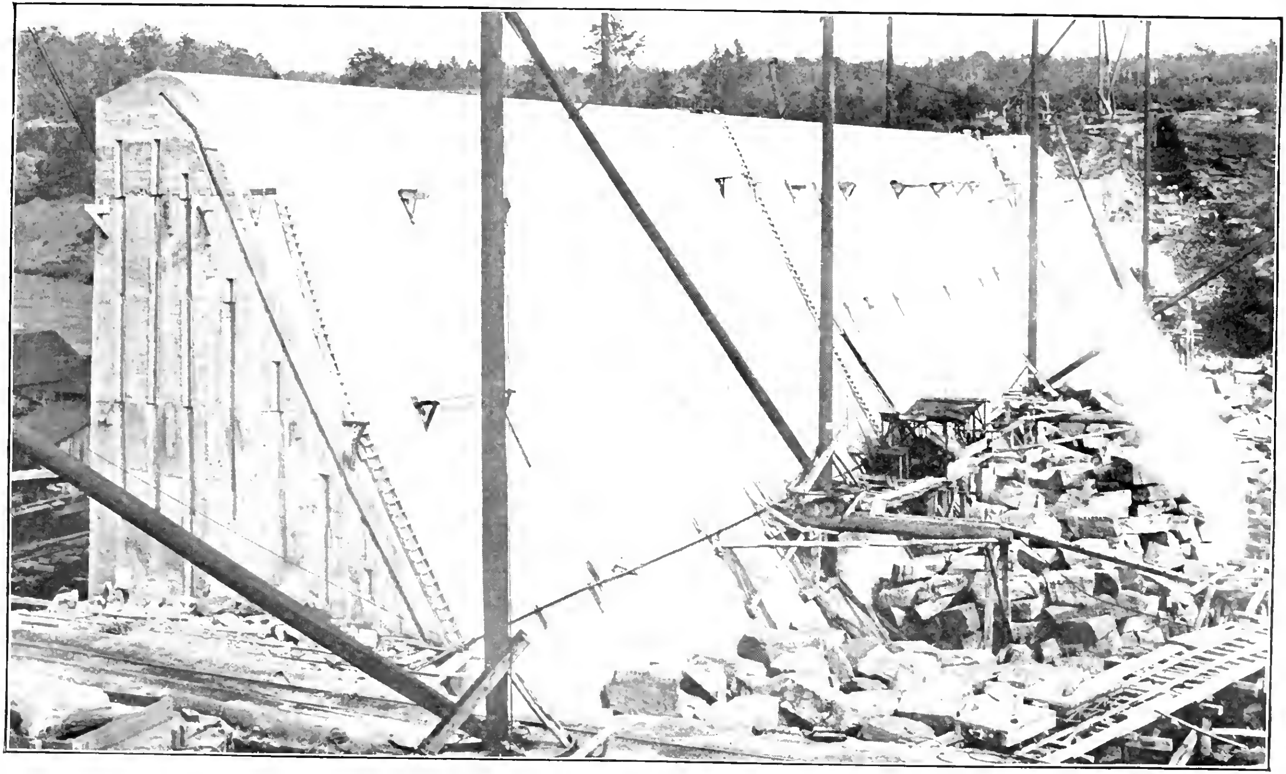
All of the lock gates are of steel, and they, as well as the various valves, capstans and other appliances at the locks, will be electrically operated. At nearly all of the locks turbines will be installed for the generation of the electricity needed.

At the flight of locks at Waterford a separate power plant will be built taking water from the Mohawk River at the Crescent dam.

Dams.

Fixed Dams.

For fixed dams a gravity type is used either straight or curved in plan with an ogee form of downstream face. The height of the fixed dam varies from about 6 ft. at the Caughdenoy dam in the Oneida River to 100 ft. for the reservoir dam at Delta.



New York State Barge Canal. Contract No. 55.

Delta Dam, Completed Spillway Section; Excavation for East End of Dam and Storage of Stones for Cyclopean Masonry.

increasing the width. As the removal of forms at the crown of the siphon would be practically impossible, iron castings were used instead of wooden forms and left in the masonry. Three vents, each 6 in. high by 12 in. long, pierce the wall at low water level above the inlet of each siphon. A little below these vents a single opening of the same size acts as a precautionary vent to break the flow in case the upper openings become clogged by freezing or otherwise. The siphons begin to discharge when the water on the open spillway reaches an elevation sufficient to fill them, and continue to discharge until the water above the spillway uncovers the vents.

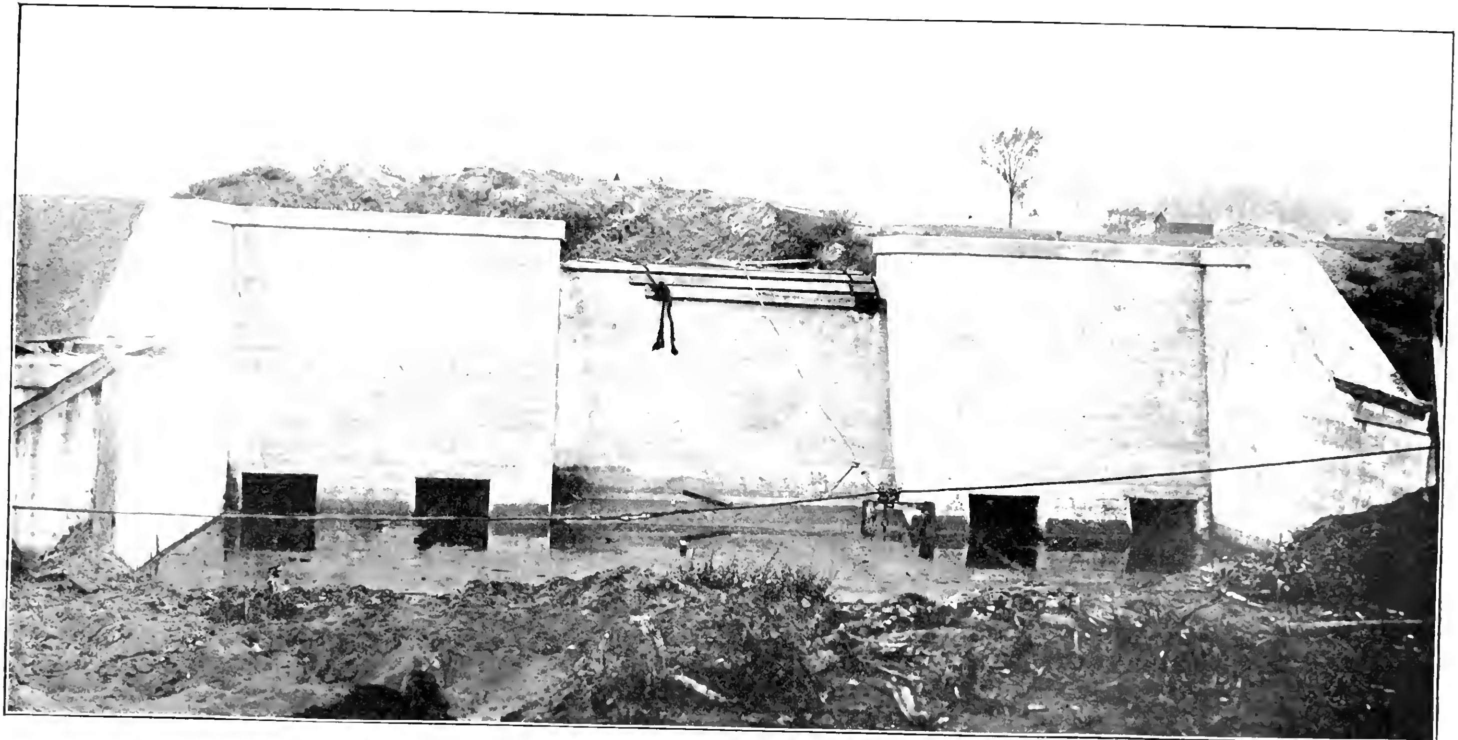
The siphon spillway on the Summit Level has been completed and is in successful operation, and a similar spillway with eight siphons instead of four is being built as an adjunct to the movable dam on Wood Creek at Whitehall.

Bridges.

Several hundred new bridges will be built over the new canal. The law authorizing the construction of the canal provides that there shall be a clearance at bridges of $15\frac{1}{2}$ ft. above the maximum navigable water surface. The greater part of the new bridges are, therefore, built as fixed bridges with the legal clearance. In a few towns and villages the local conditions are such that the construction of fixed bridges would necessitate long and steep approaches, and in other cases the approaches to fixed bridges would cause heavy damages to valuable property. In such cases vertical lift bridges balanced with concrete counterweights by means of steel cables will be used. These bridges always maintain a horizontal position and are lifted sufficiently to give the legal clearance. Stairways are constructed connecting with the sidewalks of such bridges when in raised position.

It is expected that the harbor at Tonawanda will eventually become a barge canal terminal and receive lake vessels. The bridges crossing this harbor will, therefore, be of the bascule type giving an unlimited overhead clearance. The movable bridge over the Oswego Canal will also be of the bascule type and, in so far as possible, the new fixed bridges over that canal will be so constructed that they may readily be converted into movable bridges at some future time with small expense. All movable bridges are to be operated by electric power, which is now generally available.

All bridges of less than about 200 ft. are riveted throughout.



New York State Barge Canal. Contract No. 25.

Siphon Spillway.

Those of longer spans than 200 ft. are pin-connected. Plate girders are used for a few short spans at the lower ends of locks.

All bridges in cities and towns and where there is a reasonable prospect for a future development of a large town or manufacturing center are designed as city bridges for 20-ton road rollers and for double-track electric railways where there is a reasonable prospect of the construction of such a railway. Such bridges have floors paved with creosoted yellow pine blocks, and the sidewalks are made of reinforced concrete. Bridges in country districts have yellow pine plank floors for the earlier designs and a special floor for the later designs. The special floor consists of hard maple strips about 1 in. thick by $2\frac{3}{4}$ or $3\frac{3}{4}$ in. wide (according to the thickness of the floor), dipped in asphalt of proper consistency and fastened together to form slabs by means of $\frac{5}{16}$-in. bolts. The slabs are spiked to wooden nailing strips on top of steel stringers. Where a good quality of maple is used, these floors give excellent satisfaction.

Contract Prices.

The following table shows the contract prices for the larger items of work under contract. This table shows rather large variations in prices bid for various classes of work. It should be remembered that the first contracts were let in 1905 and that bids have been received several times every year since that date. This covers at least one rather severe financial depression and two periods of increased cost of work.

Contract Prices.

	Excavation.			Concrete.			
Contract.	Nature.	Price.	Embankment.	First.	Second.	Third.	Wash-wall.
1	Dry-Wet	$\$0.57\frac{3}{4}$	$\$0.11\frac{1}{2}$	$7.75	$6.75	$5.85	$1.90
2	Dry	0.40	0.12	6.50	5.50	4.50	1.50
2-E		0.54	0.15	0	6.25	0	2.00
3	Dry	0.41	0.12	6.65	6.15	5.25	1.50
4		0.14	$0.08\frac{1}{2}$	0	5.20	0	2.12
5	Dry-Wet	$0.12\frac{1}{8}$	$0.09\frac{1}{2}$		5.65	5.25	2.35
6	Dry	$0.46\frac{1}{4}$	0.15	0	5.25	4.90	0.80
7	Bridges Contracts 2, 3, 4, 5 and 6.						
8		0.60	0.15	0	7.00	6.00	0
9		0.50	0.17	0	6.75	6.25	2.50
10		0.86	0.15	8.00	6.40	0	2.00
11	Dry	0.51	1st-0.10		5.00	0	2.00
			2d-0.05	0			
12	Div. 1-Wet	1.89					
	Div. 2-Dry	0.561	0.165	0	7.15	0	2.75
	Div. 3-D. & W.	0.308					
	Div. 4-D. & W.	0.187					

	Excavation.			Concrete.			
Contract.	Nature.	Price.	Embankment.	First.	Second.	Third.	Wash-wall.
13	Bridges Contract 18 and part of Contract 12.						
14	Dry–Wet	$0.735	1st–$0.17				
			2d–0.11	$8.00	$7.50	$6.50	$2.50
15	Dry–Wet	0.285	0.175	0	6.00	0	2.25
16	Bridges Contracts 11, 25 and 27.						
17*		0.96	0.12	0	6.50	6.30	1.50
17		0.96	0.12	0	6.86	6.30	1.50
18		0.52	0.15	0	6.25	0	1.50
19		0.60					
		0.17½	0.14	0	6.40	0	1.35
20–A	Wet	0.80	0.18	0	0	0	2.40
20–B	Wet	0.638	0.16½	0	0	0	2.20
20–C	Wet	0.51	0.18	0	0	0	0
20–D	Wet	0.51	0.18	0	12.00	0	12.00
21		0.48	0.15	0	7.00	0	1.75
22	Bridges on part of Contract No. 12.						
23		0.28	0.04	0	6.40	0	2.00
24							
25	D. & W.	0.23	0.10	0	5.75	0	1.80
26	Wet	0.34¾	0	0	0	0	0
27	W. & D.	0.26	0.15	0	6.50	0	2.00
29		0.22⅓	0.09	0	6.50	0	2.10
30		0.3375	0.15	0	6.50	6.50	2.00
31		1.25	0.14	0	5.90	0	0
32	Needle dams, locks gates and valves, Contracts 3, 25 and 27.						
33		0	0	0	9.50	0	0
34	Saratoga Avenue Bridge, Waterford.						
35		1.14½	0.12½	0	7.20	0	0
36	Operating winches for movable dams.						
37	Wet	1.74	0.18	0	6.50	0	2.00
38		0.50	0	0	7.00	6.50	0
39	Wet	0.83	0	0	7.50	0	2.45
40	Dry Wet	0.78	0.15	0	7.00	6.50	2.50
41		0.22	0.04	0	10.00	0	0
42		0.19	0.11	0	6.00	0	2.00
43	Dry Wet	0.18	0.08	0	6.00	0	1.75
44		0.20½	0.08	0	6.50	0	1.85
45	Dry	0.42	0.15	8.00	6.75	0	2.00
46	Dry Wet	0.17	0.10	0	6.25	0	0
47	Dry Wet	0.199	0.15	0	6.10	0	0
49		0.23	0.15	0	5.60	0	1.75
50		0.46	0.28	0	6.00	5.00	0
53		0.75	0.15	0	6.35	0	0
54		0.36	0.18	0	6.40	0	2 50
55		0.65	0.18	0	7.00	0	2.00
60		0.53	1st Cl 0.18				
			2d Cl 0.14	0	9.00	7.80	2.50

*Relet

	Excavation.			Concrete.			
Contract.	Nature.	Price.	Embankment.	First.	Second.	Third.	Wash-wall.
61		$0.60	1st Cl $0.15				
			2d Cl 0.12	$8.00	$7.50	$6.00	$2.50
62	Wet & Dry	0.64	0.21½	0	7.50	6.75	2.00
63		0.33	(Dry) 0.18	0	7.00	6.00	2.50
64		0.58	1st Cl 0.18				
			2d Cl 0.14	0	9.00	7.80	2.50
66		0.497	1st Cl 0.18				
			2d Cl 0.14	0	9.00	7.80	2.50
67		1.45	0.15	0	6.25	0	0
68		0.75	Wet 0.05				
			Dry 0.12	0	6.25	0	2.50
69		0.85	0.18	0	6.25	0	0
70	Wet	0.99	0.15	0	7.00	0	2.25
71	Wet & Dry	2.00	0.15	0	7.00	0	2.50
72		1.24	0	0	0	0	0
73	Wet	0.52	(Wet) 0.15	0	7.00	0	2.50
75		0	0	0	11.00	0	0
78	Wet	0.19½	0.14	0	7.00	0	2.15
79		1.00	0	0	8.00	0	0
27-A	W. & D.	0.198*					
		0.44	0.165	0	7.70	0	2.20
90		0.45	0.30	0	8.50	0	0

Costs.

The cost of excavation per cubic yard, including depreciation, interest and overhead charges, has been as follows:

Earth Excavation.

By hydraulic dredge	from $0.05 to $0.16
By dipper dredge	0.13 to 0.30
By ladder dredge	0.15 to 0.25
By clamshell dredge	0.09 to 0.15
By revolving excavators and scraper bucket	0.05 to 0.28
By towers and scraper buckets	0.11 to 0.20
By steam shovel	0.10 to 0.40
By graders	0.14 to 0.30
By hand and team	0.14 to 0.60

Rock Excavation.

Dry rock by steam shovel	$0.30 to $0.75
Dry rock by hand and derrick	2.00 (average)
Wet rock	1.00 to 2.25

* Excavation from spoil banks.

Channeling has cost from 22 cents to 38 cents per square foot, depending on the character of the rock, the rock channeled having varied from soft badly broken shale and slate to hard limestone.

The cost for second-class concrete has been from $4.20 to $7.00 per cubic yard in place, including depreciation, interest and overhead charges.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1911, for publication in a subsequent number of the JOURNAL.]

NOTES ON PILE PROTECTION.

By T. Howard Barnes, Member Boston Society of Civil Engineers.

[To be read before the Society, September 20, 1911.]

In the course of some wharf construction for the Guatemala Railway Company in Puerto Barrios, Guatemala, it became necessary to deal with some creosoted southern United States piles which had been in place for about seventeen years. These piles were nearly all of them in fair condition excepting at and near the water line, but at this belt for, say, five feet in width, most of them were badly eaten, many having cavities extending completely through them, the result of the combined activity of the teredo and the limnoria. The expense of replacing these piles with new ones would approximate fifty dollars each. The incentive for saving them by placing some reinforcement was so great that the writer gave much time to its consideration.

The first idea was to place such reinforcement by using a chamber clam-shell like, each half of which should have a semicircular opening in the parting line of the bottom for embracing the pile when clamped about it, and which would admit a workman after unwatering the chamber, the annular space about the pile being first calked. A test chamber was made, but trials in controlling it against the effect of even a wind-chopped sea of moderate force proved the futility of rapid and economical manipulation, and the idea of working in the dry was abandoned. Had the apparatus proved successful it was proposed to place a reinforcement of nails, poultry netting and cement mortar, similar to that hereinafter described for protecting some of the piles which were placed in the new construction.

Accordingly, forms were prepared for placing in the wet about the old piles a reinforced cement-mortar envelope which should have a width of about 8 ft. and a minimum thickness of 2 in. These forms were made of No. 26 gage galvanized iron shaped into cylindrical shape with a slight taper and 10 ft. in length. A 2-in. by 3-in. strip of pine having a length of 8 in. greater than the form was attached on each side of the parting line, which was up and down. The metal was folded about the strip an inch on to the three-inch side, leaving two inches for attaching an oakum strand, which was needed to prevent egress

of mortar. Two 2-in. by 4-in. stiffeners of same length as the facing strips were fastened to the form at the one-third point as shown in the cut, Fig. 1. A collar of 2-in. stock made from narrow blocks was provided at the foot to serve as a gage for

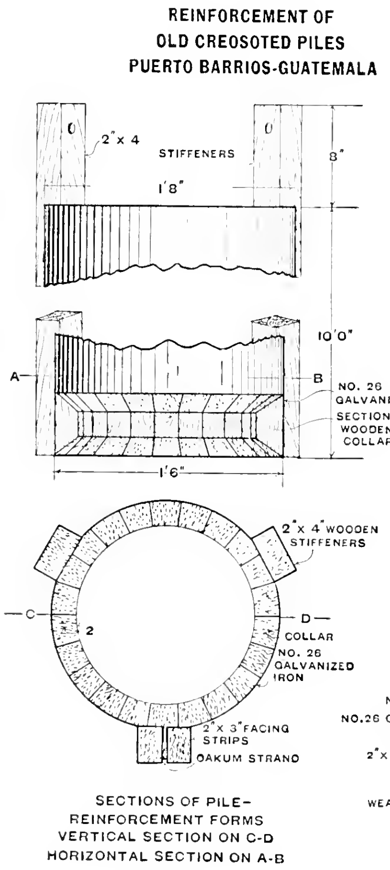


Fig. 1

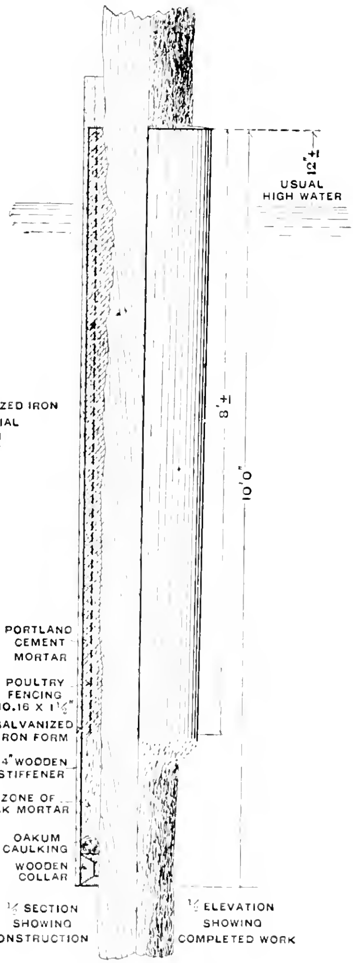


Fig. 2

regulating the thickness of the mortar, as well as serving to calk against in closing the foot against the escape of the mortar.

The mortar envelope was reinforced by a wrapping of poultry fencing of No. 16 gage with 1½-in. mesh. The procedure was,

first to scrape off the mussel growth on the pile to be treated. This growth forms a complete mat, but is detached quite readily. The poultry fencing is then put in place. This is made up into a roll, 8 ft. long, and having enough fullness to lap on to itself several inches when placed about the pile. The form, nearly buoyant with the stiffeners, is then floated into place, first having been provided with a wreath of fluffy oakum affixed to the collar. The facing strips are closed tightly with carriage clamps hung from them by cords of such length that when the clamps are squared into horizontal position they are in the proper place for screwing up by the divers. The divers are naked, and their further duties are to close the bottom of the form effectually against the egress of the mortar, watching carefully that none is escaping at the time of the filling. Steel bars 8 ft. long of ½-in. stock are hung, one in each of the three sections of the form. They have a shepherd's crook for support on the top edge of the form, and are used for slushing the mortar into compact state as it fills.

The mortar is made, one part cement to about two parts sand, the latter being silica and selected as coarse as possible, say 0.18 mm. effective size. It is assured that there is a little overfill of cement. The operation of filling is carried on rapidly, the effect of the slushing rods being supplemented by tapping with clubs on the stiffeners, resulting in securing a sound mass excepting in the lower zone of about eighteen inches.

It will be noted that the forms were made 2 ft. longer than the reinforcement cage. The separating of the sand from the cement in the lower portion could not be avoided under the limitation of having to drop the mortar through so great a depth of water; accordingly the reinforcement was made to occupy only the sound part of the envelope.

Fig. 2 shows the construction and the finished appearance of the work. At the time of writing, the work is still in progress, with a record showing no failures. It should however be added that at times much delay is caused by difficulty in sealing the foot of the form. It is useless to place the mortar when any is escaping at the bottom.

The expense of this treatment is, — labor (contract price), \$8; materials (cement, fencing, etc.), \$4; a total of \$12, to which should be added the expense of experimenting and overhead charges.

There seems good reason to expect a further life of the piles thus treated as great as that at present sustained.

Protection of Piles before Driving.

There was also used experimentally on some of the creosoted piles in new construction in the same work a reinforced mortar protection applied in the following manner: First, wire nails — about 12*d.* — were driven thickly over the protected zone for one third their length, the zone being 10 ft. wide; next, the nails were bent over, using in this operation a short length of small iron pipe, which was not only expeditious but prevented the nail from making the angle close to the wood; a wrapping of poultry fencing of the before-described class was then attached; a coat of Portland cement plastering was then applied, being thoroughly troweled in; this was about $\frac{3}{4}$ in. thick and was treated when set by a grout wash of Portland cement mixed in a solution of water glass. The envelope was kept wet until well set. In respect to the water glass it is too early to note its effect in resisting the action of sea water.

The driving of these piles showed the following features of interest, the hammer used being a regular drop-hammer weighing 2 500 lb. Confining the drop to 4 ft., the envelope was nearly invariably kept intact; above this limit of drop the mortar was detached more or less, occurring nearly always at those places in the envelope where the fencing was in contact with the wood; the mortar was also weakened and became detached through the influence of the creosote which had cooked out of the pile and permeated the mortar as it lay in the yard exposed to the direct sun rays.

The cost of this form of protection was, — labor (contract), $1.20; materials, about $2.50; a total of $3.70, exclusive of overhead charges. It must also be observed that the handling cost in placing the piles in the yard in position to be treated was additional and amounted to a considerable item. This expense applied of course in the case of any desired treatment, such as coppering, etc. More care in dragging out the above-described piles over the ground from the yard was actually required than in the case of those protected with copper yellow-metal. The expense of yellow-metal covering in 20-oz. weight was three times that of the mortar protection.

Conclusions. — If the netting be placed so as to be free from contact with the wood, leaving a clear space of about $\frac{1}{4}$ in. for the mortar to enter and get a grip of the wire, ordinary handling with careful driving will not injure the envelope; certainly the use of a steam hammer would insure entire freedom from damage in driving. When applied to creosoted piles there should

be maintained a shade to prevent the exuding otherwise of a serious amount of creosote under the heat of the direct sun rays.

General. — It may anticipate some reader's query, " How do you account for the confining of the activity of the sea pests to so narrow a belt? " to remark that the clearness of the water seems to govern the activity of the teredo and of the limnoria. The Puerto Barrios harbor bottom is a mineral ooze, very easily stirred up. Other localities, like Port Limon in Costa Rica, where the limnoria has been active enough at depths of 25 ft. to eat off creosoted piles in seven years, having clear water to the bottom, show an activity of the borers, which, while greatest at the water line, extends to the ground.

Local conditions of murkiness of water may account for curious differences of such activity in neighboring wharves which the writer has had cited to him as occurring in our northern waters.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1911, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF PAPER, "A NEW THEORY FOR THE DESIGN OF REINFORCED CONCRETE RESERVOIRS."

(Volume XLVI, Page 391, June, 1911.)

Mr. Alfred D. Flinn. — Mr. Andrews' paper on design of reinforced concrete reservoirs in the June, 1911, Journal, and the discussion of that paper, constitute a valuable contribution to the working literature, not only of concrete standpipes, but of reinforced concrete conduits and similar structures. The theory advanced contains a number of elements which were adopted about two years ago by the engineers of the Board of Water Supply of the City of New York for the design of reinforced concrete pipes, based upon numerous large experimental pipes, laboratory tests and theoretical investigations. I have asked Designing Engineer Fred F. Moore, of the Board's staff, to state this theory, with a brief description of the resulting designs.

In reading the paper and discussion, the writer is impressed with the lack of mention of one important feature of the treatment of concrete structures intended to contain water as well as of other concrete structures, namely, the necessity for keeping the concrete moist or wet all the time after the forms are removed for about two weeks, unless it is sooner covered with earth or other permanent protection. Tests show that concrete, which hardens wet suffers little or no shrinkage and is denser than that which hardens dry. Examples of the value of keeping concrete wet came to the writer's attention on a recent visit to Portland, Ore., and Seattle, Wash., in both of which cities large new distributing reservoirs were being lined with concrete. In both places effectual care was exercised to protect the freshly deposited concrete from the hot sun and to keep it well moistened by almost continual spraying. As a result, so the writer was informed, no cracks were observed in acres of lining 7 or 8 in. thick, divided into blocks as large as about 16 by 30 ft. The proportions of the concrete at Portland were 1 : 2 : 4 and at Seattle 1 : 3 : 6. In both places a layer of mortar was applied to the top before it had hardened. About four years ago the writer built a reinforced concrete house about 42 ft. square, with walls 8 in. thick, lightly reinforced with round rods. The concrete was

kept moist and to date no cracks have been discovered. It is absolutely proof against hard rains and all other moisture, although there are no air spaces in the walls and the interior plaster was applied directly to the concrete, without furring. The mixture was 1 part of vulcanite cement, 2 parts of Cow Bay (Long Island) sand and 4 parts of $\frac{3}{4}$-in. broken trap rock, deposited quite wet.

Numerous experiments at the Board of Water Supply laboratory and experience in actual construction have shown the futility of attempting to make concrete watertight by mixing with it any of the so-called waterproofing compounds or by applying subsequently a surface plaster. One common fault of plasters is that they are made of a much richer mixture than the mortar in the concrete to which they are applied and, consequently, behave in a different way as they set and harden. No better means for making concrete watertight, and at the same time gaining advantage in strength, has been found than the liberal use of cement, intelligent grading of the aggregates, thorough mixing and placing, and conscientious moistening after removal of the forms.

Repeated observation leads the writer to believe that much concrete is insufficiently mixed. A few years ago Mr. Thomas A. Edison made a series of experiments at the Edison Cement Works which seemed to support this idea, which is also substantiated by experience.

Reinforced concrete containing a large proportion of its bulk of steel, or rather, having a large surface area of steel, needs a decidedly larger proportion of mortar and water than concrete containing no steel. Thin sections also need more water than thick ones because of the water lost through, or taken up by, the forms, especially if these are of wood.

Steel for reinforcing concrete structures to contain water should be so deformed and so distributed through the concrete, in members not too large, as to work with the concrete to the fullest practicable extent in resisting stresses, and so arranged as to make readily possible the placing of the concrete in such manner as to assure thorough continuity, complete contact with the steel, and the maximum density throughout. Concrete constructors have recognized that this requires more skilled labor and more intelligent supervision, and owners must recognize that it is worth more money and should be paid for accordingly.

Mr. Andrews' tensile tests of concrete are interesting but could be used with more confidence if he would supply further

details as to how thoroughly the specimens were rammed into the molds, how they were treated until the time they were tested, and by what means they were broken. A statement in the paper indicates that the concrete was made with gravel. Would it not have been stronger if made with broken stone?

Methods of treating the joints between days' work in concrete or between successive batches have been so successfully developed by Emerson & Norris, of Boston, in architectural work, that even on close examination no appearance of such joints can be detected. Apparently equally successful methods for securing continuity at joints are desirable for hydraulic structures. Until such methods are reliably developed, it would seem advisable to insist upon continuous work in the walls of concrete standpipes to some distance above the so-called critical joint. In some cases, however, this may not be feasible.

Some remarks in the discussion lead the writer to believe that possibly in some cases condensation on the outside of concrete standpipes has been mistaken for seepage, or, on the other hand, that the apparent lack of seepage on bright dry days has been due to the rapid evaporation.

Esthetic consideration of engineering structures, especially those so conspicuous as water towers or standpipes, is increasingly important. The writer believes that the time is already fast approaching when it will be considered as great a moral crime to affront the good taste of our fellow citizens as to jeopardize their health. Why should we not seek to beautify our communities and our country by our works instead of disfiguring otherwise beautiful scenes? Europe is finding to-day that beautiful public works and buildings constructed in days gone by are genuine assets in attracting tourists, with the consequent financial advantage.

As a detail in improving the appearance of concrete structures, a non-staining cement is highly desirable. Cannot cement manufacturers produce a cement which, while losing none of the good qualities of the cement now offered, will have very decidedly less tendency to effloresce or otherwise cause disfigurement of the structures in which they are used?

The writer joins with others in expressing the hope that Mr. Andrews will find it convenient to answer several questions which have been raised in the discussion.

Fred F. Moore, M. Am. Soc. C. E. — One of the types of New York City's Catskill aqueduct designed for construction in open cut is a concrete section, reinforced with two rings of

steel rods and a nominal amount of longitudinal reinforcement. This section was selected for those places where the aqueduct is slightly below the hydraulic gradient as being more economical, while at the same time, if adequately designed and properly constructed, as safe and certainly as permanent as any other types of pressure aqueduct conceived for construction in open cut. These stretches of reinforced concrete aqueduct are relatively short and under heads exceeding in no case 50 ft. on the center of the pipe. The Kensico bypass, 12 170 ft. in length, is the longest. This is 11 ft. inside diameter and under a head of 11.5 ft. on the center for the ordinary conditions, but a possible emergency head of 42.5 ft. had to be provided for. Other stretches of this kind of aqueduct, including three Venturi meter tubes, aggregate about 3 800 ft. The diameters vary from 7 ft. 9 in. at the throat of the meters to 17 ft. for the largest aqueduct, and working heads on center of aqueduct are from 12 ft. to 48 ft.

This reinforced concrete aqueduct presents a problem in design somewhat similar to the reinforced concrete reservoirs, but differing, in that the loads producing stresses are far from uniform around the circumference. These aqueduct sections are loaded internally and externally. The internal load results from a head of water in most cases not more than two or three times the diameter, giving a pressure at the bottom greater than at the top. The external loads producing stresses, including the weight of the masonry, as well as refills and embankments, are far from uniform. In one case the section is subject to the loads resulting from the crossing of a steam railroad. Such loading as this introduces into the rib, besides direct stresses, flexural stresses of magnitude requiring serious attention.

Early in the studies looking to the design of this type of aqueduct, the basic principles set forth by Mr. Andrews were recognized as essential in obtaining water tightness and adequate protection for the steel. Besides the loss of water and other evils incidental to leakage, which obtain, in general, for all types of aqueduct, we have the peculiar objection in the type under discussion that leakage past the reinforcing metal would undoubtedly give rise to corrosion and subsequent erosion of the steel. In removing some reinforced concrete test pipes, considerable pitting was observed where reinforcement passed through porous portions of the concrete. Examination of the water from a leak of 95 gal. per twenty-four hours was found to contain 4.9 parts per million of iron, or this leak carried off iron at the rate of nearly 8 in. of $\frac{3}{4}$-in. round rod per year. This leak

produced iron stains on the side of the pipe and upon fabric suspended near it. That iron was taken up from the steel reinforcing bars in considerable quantity by the leaking water is further evidenced by analyses of water leaking through other parts of this pipe which had an iron content of only 1.5 parts per million, presumably obtained largely from the cement and aggregates of the masonry. Accordingly, the condition was imposed that the concrete, when acting with the steel in tension, should not be stressed to the breaking point. Furthermore, the stress in the steel when acting alone, at an accidental joint which might form in the concrete, must be so low that the opening of the joint, through stretching of the metal, would not be wide enough to permit the passage of water.

When the studies were undertaken, the only pipes of this kind on record were some constructed by the United States Reclamation Service. While these pipes were reasonably tight, a study of the conditions indicated that a considerable turbidity of the water was a material factor influencing the leakage. It appeared that cracks in the concrete were probably closed by the entrained fine silt extracted from the water. As appreciable silting of cracks could not be expected from the clear potable water which is to flow in the Catskill aqueduct, tests under conditions approximating as closely as possible those of the actual service appeared justified as a precedent to the design of such important structures. These reinforced sections are for the most part an integral part, in a single unit in any one place, of the main aqueduct, and should be as tight, safe and lasting as the standard plain concrete section which is liberally designed that it may give long continuous service.

A test section 11 ft. in diameter and 210 ft. long was constructed on the aqueduct line in the bottom of one of the moderate depressions, to become, if found satisfactory upon test, a part of the permanent structure. This test section was 8 in. thick, reinforced with rings of twisted square bars in part with single rings of $1\frac{3}{8}$-in. bar, $4\frac{5}{8}$-in. spacing, and in part with double rings of 1-in. bar, $4\frac{15}{16}$-in. spacing. The concrete was mixed in the proportion of one volume of cement to $5\frac{1}{2}$ volumes of aggregates, broken stone with sand and with screenings, and gravel with sand being used. Beam tests of the concrete indicated by the common straight-line formula an average tensile strength of about 400 lb. to the sq. in., the minimum strength being 321. On account of the reduction of the modulus of deformation of concrete as the tensile stress approaches the ultimate strength,

the actual tensile strength of the concrete may be as much as 20 per cent. under these values. The pipe was tested when six and one half to eight months old. This pipe was quite satisfactory when tested up to pressures of about 40 lb. to the sq. in., but leaked through joints which formed in the concrete at higher pressures. Up to 40 lb. the tests showed the small leakage consistent with the ordinary laws of percolation through concrete. Above this pressure, the percolation increased rapidly, and at the higher pressure, 54 lb., numerous longitudinal cracks formed, some large enough to be plainly visible on the outside, but mostly small and visible only on the inside while drying. On the average a longitudinal crack appeared for about every six inches of the upper part of the circumference.

These tests confirmed quantitatively the strong qualitative impression already formed as to the control of stresses in the materials necessary for a reasonable measure of water-tightness. An analysis of the results, supported to some extent by experience with similar pipes constructed by the Reclamation Service, led to the adoption of 200 lb. per sq. in. for maximum working tensile stress in concrete, concrete and steel acting together, and 6 000 lb. per sq. in. for maximum working tensile stress in steel when concrete takes no tension as at an accidental joint. The sections were investigated for controlling load conditions at all critical planes with reference to both of these conditions, but it was discovered that, in general, the design of steel to take all of the stress met the condition imposed for stress in concrete and steel acting together.

Study of these test sections and other observations on behavior of concrete showed, among other things, the particular importance in these structures of keeping the concrete wet until thoroughly set. If the masonry is allowed to set dry, the shrinkage may produce an initial tensile stress in it, with a corresponding compression in the steel, which, together with the load stresses, may break the concrete. Even with the best of management, the initial stress in the materials due to shrinkage of the concrete is an uncertain factor, which must, in the design, be recognized in determining the quantity and distribution of materials.

When concrete is cast against a smooth metal form, there is produced a surface skin which, compared to the bulk of the concrete, is highly resistant to the passage of water. Some laboratory tests made in connection with this and other work indicated the porosity under water pressure of 1 : 2.6 : 4.9 concrete 6 in.

thick with surface skins intact to be only 1.2 per cent. of same concrete without surface skins. The value of the two surface skins in resisting the passage of water was accordingly equal to many feet of concrete. This proportion would undoubtedly be reduced with a concrete richer in cement, but nevertheless, the conclusion is warranted that the tightness of a concrete pipe depends in large measure upon the continuity of the surface skins, particularly the interior one. Screenings were found not as satisfactory as natural sand in producing a uniformly dense concrete with a satisfactory surface skin.

Experiments with the test sections showed that the pressure cracks differed from the original porosity of the concrete, in that they did not tend to silt up. On the contrary, the pressure cracks seemed to enlarge with repeated applications of the pressure, which is not surprising when it is remembered there is but little besides the friction between the steel and concrete to prevent the whole elongation of the steel appearing as cracks in the masonry.

The designed sections differ somewhat, in appreciation of varying local conditions, but the section presented for analysis of stresses was essentially a masonry ring with transverse steel rods embedded near the inner and outer surfaces. The masonry is gradually thickened somewhat from the top toward the horizontal diameter and considerably at the side-bottom for an adequate foundation bearing. For construction in deep rock cuts advantage is taken of side support and anchorage, afforded by the rock contact, in a special section designed with thinner rib below the horizontal diameter and the omission of steel from the bottom. The steel is everywhere covered by a nominal thickness of not less than 4 in. of concrete. This concrete cover, which appears excessive when compared with good reinforced concrete design under some conditions, is believed to be justified in these water-carrying structures by the importance of having a sufficiently ample concrete protection for the steel, after a reasonable allowance for unavoidable inaccuracies in placing.

The economical shape of masonry section and relation between concrete and steel areas had to be determined by comparison of trial sections, the design of each one of which was perfected sufficiently for the purpose only. In each case, several possible loadings had to be independently investigated to discover the critical condition.

The method adopted for stress determination was largely a graphical one. Resultant force lines were drawn in the usual

way; that one which fixes the position of the center of internal stress in the materials being determined by applying the "least work" criterion. This theorem of Castigliani recognizes that the distribution of stress in a stable, elastic rib supporting external forces will be such that the aggregate work performed by the internal forces, or stresses, is a minimum. In these sections, the external forces were in all cases symmetrical about the vertical axis, or so nearly so that the direction of resultant forces at middle of crown and invert could be taken as horizontal. The true line had to be sought by the laborious "cut-and-try" process, but experience soon gave such adeptness that the line could generally be determined nearly enough for practical purposes in three or four trials.

It is unnecessary to determine the actual work done, as, with a fixed condition of external loading for any rib, there are certain terms and factors in the expression for total work which are common to all assumed positions of the resultant force line. The resultant force line corresponding to least work done by internal stresses is indicated by the line giving the least summation of the values of $\frac{M^2}{I}+\frac{P^2}{A}$ (1), in which

A = area of concrete section of an assumed radial plane.

P = component of resultant force normal to the assumed radial plane.

I = moment of inertia of concrete section of the assumed radial plane about its center of gravity.

M = bending moment of force P.

In expression (1), the first term refers to the influence of the force P in producing flexure, and the second term to the direct stress influence.

For convenience, a length of 12 in. of section was considered in the analyses, and all quantities were taken in inches and pounds. In all of the cases studied, P was a tension force, but a condition of loading is possible in such structures which would make it more convenient to approach the problem in such a way that P would become for a portion or all of the rib a compressive force.

The obvious value for I in the test expression is the moment of inertia of the reinforced section with respect to its neutral axis when under the stress conditions obtaining, but the use of the moment of inertia of the plain concrete section, neglecting the steel, with respect to its center of gravity will indicate the same resultant force line.

When, as in these sections, reinforcement consists of bars of equal area symmetrically placed with respect to an axis through the center of gravity of the concrete section, the neutral axis of the reinforced section for consideration of flexural stresses alone coincides with that of the plain concrete section, if the modulus of elasticity of steel and concrete are taken as respectively constant and of the same value for both tension and compression. This is a reasonable assumption within the limits set for the working stresses. The moment of inertia of the reinforced section is larger than that of a plain concrete section of the same shape and area, but by a quantity which is constant in each joint for all values of M; hence the moment of inertia of the plain concrete section may be used in the test expression as a measure of the work done by internal stresses, for we are concerned with differentials only and not with actual values. When there is a direct stress along the axis of the rib in addition to flexural stresses, the neutral axis is no longer at the center of gravity of the section, but I occurs in that part of the test expression indicating flexural stresses only in which the moment of inertia of the plain concrete section may be properly used. If the concrete cracks, the steel must carry all the tension and the neutral axis will move away from the center of gravity of the concrete section by a quantity constant for all values of M, depending only upon the stresses in the steel and concrete and the relation between the moduli of elasticity of these materials. Since the difference between the axes is constant, the difference between the true moment of inertia of the section and that of the plain concrete is constant, and a constant error in the moment of inertia has no influence upon the determination of the resultant force line.

For all cases, then, the moment of inertia of the plain concrete section, with respect to its center of gravity, may be used for I in test expression (1) for finding the true resultant force line. Substituting for M its equivalent $P \times n$, and canceling constants, the expression becomes $\frac{P^2 n^2}{h^3} + \frac{P^2}{h}$ (2), where

n = distance from point of application of P to center of radial plane.

h = length of radial plane.

Having determined the true resultant force line and the force polygon, the values of the components of the resultants normal to the assumed planes and the eccentricity of applica-

tion of each are obtained from them. With these data, the maximum tension in the steel and other stresses for each assumed plane are computed and the size and spacing of the rods chosen to best meet the requirements.

For cases where the concrete is assumed to take its proportionate part of the tension, the presence of forces producing flexure does not cause any movement of the neutral axis and the solution of stresses does not differ from that of any homogeneous beam, except that the steel must be recognized in determining the value of the moment of inertia.

The condition assuming no tension in the concrete presents three distinct cases for solution: (I) When the reinforcement on both sides of the rib is in tension and no compression is present in the concrete; (II) when part of the concrete, including one reinforcing bar, is in compression while the other bar is in tension; and (III) when the reinforcement on both sides is in tension and there is still some compression in the concrete.

The first case obtains when the resultant external force intersects the assumed radial plane near its center and is solved by resolving the component of the resultant external force to the radial plane into two parallel forces acting at the centers of the steel bars. For the solution of cases II and III a cubical equation was derived containing two unknown quantities, — the area of the steel, and the distance from the neutral axis to the most compressed fiber of the concrete. This was solved by trial, first assuming a value for the steel section (preferably, of course, the area of some commercial size of rod or a multiple of it). It was found that graphical devices aided to some extent in this step.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVII. OCTOBER, 1911. No. 4.

THE ENGINEERING PROBLEMS OF LAND RECLAMATION.

BY A. M. SHAW, MEMBER OF THE LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, April 10, 1911.]

IN the reclamation of lands for farming or other purposes, the incentive is usually a commercial one. This is almost invariably the case in regard to works carried on in this country, and in a broad way applies to the draining of the marshes along the Atlantic coast and on the Canal Zone, where swampy places are being drained to get rid of the mosquito pest. Considering the troubles experienced by the French, it is probable that in the canal construction our government has received, in actual increased efficiency of the working force due to improved sanitary conditions, more value than the investment represented in the work of sanitation. Reclamation work is occasionally undertaken, however, the cost of which is so great that no adequate cash returns are expected. This is notably true of some of the projects of Holland, where the engineers admit that the profits will never reimburse the government for the investment made, the prime incentive being political and humanitarian. The little Dutch monarchy has become so thickly populated that, in certain sections, the living conditions have become intolerable and the people have been forced to a policy of expansion to prevent the only alternative of emigration of their thrifty farming population to other countries.

In the United States we have the following types of land

which require careful and scientific treatment in order that they may be rendered fit for cultivation:

1. Arid lands.
2. Lands impregnated with chemicals injurious to plant life.
3. Exhausted lands.
4. Wet lands.

Since the federal government has gone into the real estate business by irrigating and marketing great areas of the arid West, the first-named class of lands and the methods employed in reclaiming them have become quite generally known. Some of the most daring stunts in dam construction have been pulled off during the past decade, and many new methods have been developed. While some of the government projects have not proved to be the success that it was hoped they might be, they have quite generally been planned along rational lines and have added materially to our national resources. It is hard to imagine a sight more pleasing than that of a well-tilled, irrigated valley set in between arid mountains. The appreciation of the scene is often enhanced by the experiences of the trip preceding, through vast stretches of rock, sand, dust and mesquite. Evidences of irrigation works which were constructed in prehistoric times have been found in the southwest, and some portions of the old canals have been appropriated and made a part of a newly constructed irrigation system.

In the central portion of Old Mexico are numberless examples of old-time irrigation systems. These quite generally bear evidence of good workmanship and show the wonderful adaptability and ingenuity of the artisan priests who accompanied or followed the Spanish invaders. Many of the designs are excellent, but the most of the older dams owe their permanence as much to the good material and workmanship as to exceptional design. In fact, after traveling hundreds of miles through the great central plateau of the republic, and viewing numberless wrecked dams and abandoned canal systems, one is led to ask himself if possibly these fine old dams that have stood perhaps for centuries are not simply other examples of the "survival of the fittest." Some of the dams now standing show the most flagrant disregard of established engineering principles. These old-time builders used a very large factor of safety as to the overturning moment, labor being cheap and good building material near at hand. Until recently very little Portland cement has been used in the country districts.

On an out-of-the-way hacienda in the western portion of the

state of Aguascalientes is an interesting example of an engineer's plans gone wrong. A dam of fifteen or twenty meters in height was to be built, but there was no local engineer of sufficient experience to prepare the plans. One of the influential men of the place undertook to obtain the assistance of an English engineer with whom he was acquanited. Surveys were made by local talent and all data mailed to England, where detailed plans were prepared. These plans were closely followed by the builders excepting that the position of the dam was reversed, in order that, as the engineer in charge put it, the extra material at the toe of the batter might hold the dam down. The structure still stands without showing any serious effect from its recent reverses.

The alkali lands of the West furnish the most common example of soils containing chemicals detrimental to plant growth. Continued irrigation, especially if carelessly done, usually results in bringing quantities of soluble alkali to the surface. At the foot of irrigated slopes, the seepage water from the higher lands brings the alkali to the lower fields, which are often so situated that no outlet for proper drainage can be secured. The only cure for over-irrigated lands or for those heavily impregnated with alkali is the construction of complete subdrainage systems, thus permitting a downward movement of water which washes and purifies the soil.

In a recent paper read before the Illinois Clay Manufacturers Association, Mr. C. G. Elliott, chief of drainage investigations of the United States Department of Agriculture, states as follows:

> "There are not less than 800 000 acres of irrigated lands in the West which require draining. Some of this area is abandoned and useless because of oversaturation and because of evils that follow in the train of seepage. The opening up of newly irrigated lands is yearly increasing the areas which require draining."

Strange as it may appear, drainage works are almost invariably required sooner or later in irrigated sections. This is especially noticeable in the Crowley district, where it has been found that the drainage of rice fields is an imperative necessity if successful rice growing is to continue.

The reclamation of farms which have been abandoned on account of the depletion of valuable soil elements by unskilled farming is a most fascinating work. Accounts of crops raised on worn-out and abandoned New England farms through judicious tilling and cropping often read like fairy tales, and one would be

inclined to doubt their truth if the stories were not well substantiated. As few of the problems of such reclamation work come to the engineer in ordinary practice, however, no discussion of them will be attempted.

Of the lands requiring drainage in order that they may be successfully cultivated, we have in addition to the over-irrigated lands already mentioned, the following types:

1. Land-locked marshes and sloughs, of which the Florida everglades are an example.

2. Lower lands of river valleys, or "second bottoms," as they are sometimes called.

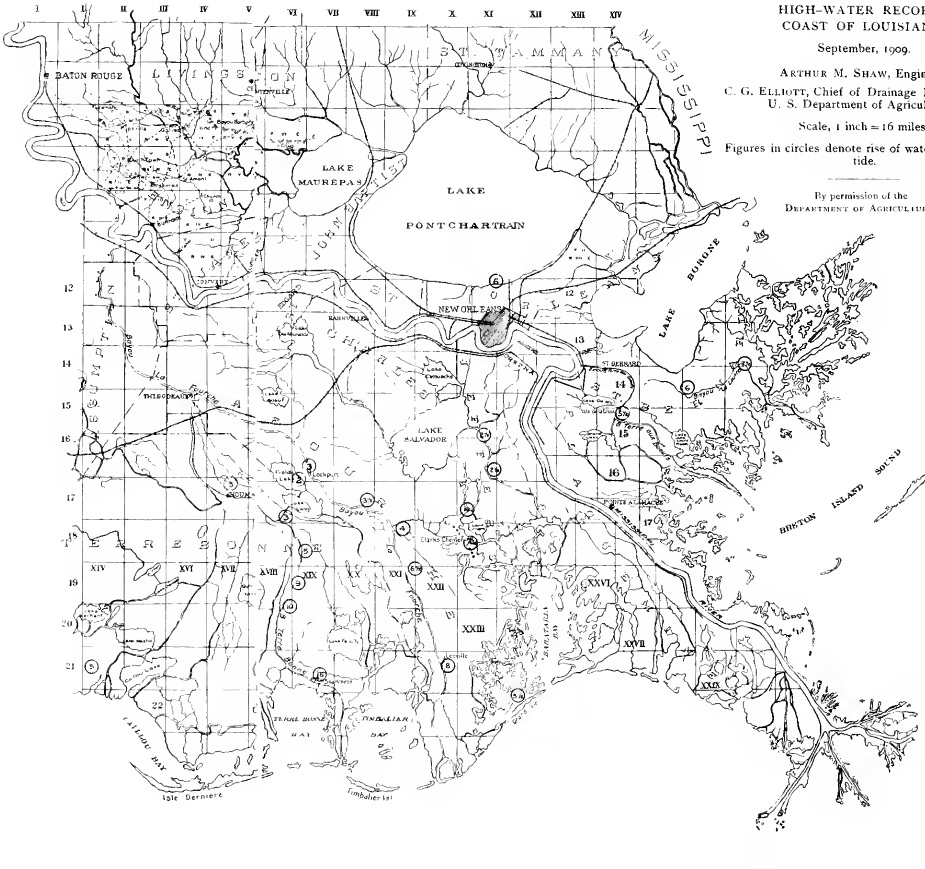
3. Seacoast marshes, usually subject to overflow by ordinary lunar tides.

4. Deltas of great rivers. These are usually only slightly above mean tide level, and may or may not be subject to overflow from ordinary tides.

Considerable literature exists dealing with the first two sets of conditions, where drainage may usually be secured by gravity. The glacier-scoured regions of the north central states furnish many examples of fertile basins and river valleys that have been drained at a cost of from two to twenty dollars per acre, and they are now referred to as the "best in the country." In the proceedings of the various state engineering societies are found much interesting and valuable data that have been developed in this class of work.

Here in New Orleans we are most interested in the problems presented in the reclamation of the delta lands of the Louisiana coast, but the engineer finds a scarcity of literature bearing on the problems which he meets. Few people of intelligence doubt the fertility of these soils, but the feasibility of their reclamation is open to an honest difference of opinion. The most serious obstacle is not our excessively heavy rainfall, but it is the difficulty of constructing permanent levees to a sufficient height to protect the lands from the high wind tides that occasionally visit these sections.

The rise of water resulting from the great hurricanes that occur at infrequent intervals along the Louisiana coast has been found to vary from a hardly perceptible tide on some of the inner lakes and bayous to an extreme rise of 15 ft., which occurred at the mouth of the bayou Terre Bonne on September 20, 1909. A study of the tide curve resulting from this storm, as illustrated by sketch No. 1, is both interesting and instructive. It was found that while the rise at Timbalier Island, several miles out in



HIGH-WATER RECORDS
COAST OF LOUISIANA,

September, 1909.

Arthur M. Shaw, Engineer,

C. G. Elliott, Chief of Drainage Investigations,
U. S. Department of Agriculture.

Scale, 1 inch = 16 miles.

Figures in circles denote rise of water above mean tide.

By permission of the
Department of Agriculture.

inclined to doubt their truth il
stantiated. As few of the prol
come to the engineer in ordinary
of them will be attempted.

Of the lands requiring drai
successfully cultivated, we have
lands already mentioned, the fo

1. Land-locked marshes ar
everglades are an example.

2. Lower lands of river va
they are sometimes called.

3. Seacoast marshes, usua
nary lunar tides.

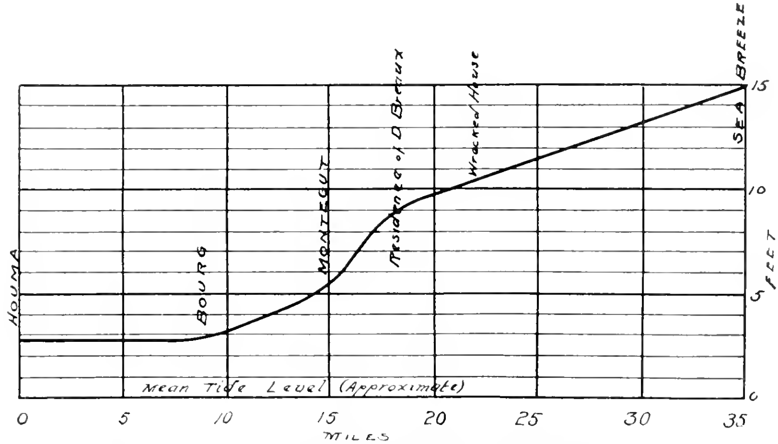
4. Deltas of great rivers.
above mean tide level, and may
from ordinary tides.

Considerable literature exi
of conditions, where drainage n
The glacier-scoured regions of
many examples of fertile basins
drained at a cost of from two to
are now referred to as the " bo
ceedings of the various state eng
interesting and valuable data
class of work.

Here in New Orleans we ar
presented in the reclamation o
coast, but the engineer finds a
the problems which he meets.
the fertility of these soils, but t
is open to an honest differen
obstacle is not our excessively
culty of constructing permane
protect the lands from the h
visit these sections.

The rise of water resultin
occur at infrequent intervals a
found to vary from a hardly pe
lakes and bayous to an extren
the mouth of the bayou Ter
A study of the tide curve resul
by sketch No. 1, is both int
found that while the rise at Ti

front of this bayou, was not of a sufficient height to drown cattle which were pasturing on the island, the combined effect of the re-entrant angle of the shore line and the rapidly changing direction of the hurricane caused the water to rise to a height of 15 ft. at the mouth of the bayou Terre Bonne, 36 miles below Houma. From the mouth of the bayou, the flood line falls in a fairly regular curve to 9.25 ft. at the residence of D. Breaux, 17 miles up the bayou, and to 3 ft. at Houma, 36 miles above the mouth of the bayou. At Grand Isle the rise in the bay back of the island was $5\frac{1}{2}$ ft.; in fact, no places were found where the rise greatly exceeded 6 ft., excepting at the mouths of bayous Terre



TIDE CURVE. BAYOU TERRE BONNE, SEPTEMBER 20, 1909.
SKETCH NO. 1.

Bonne and La Fourche, and on the extreme southeastern coast. On the bayou La Loutre a rise of 7 ft. is recorded. The effect of this particular storm was felt throughout the entire coast country, though no serious damage was done west of the Atchafalaya River. At the mouth of this river the rise was about 5 ft. Your time has been taken in the foregoing discussion of one particular storm, not on account of the resulting loss of life and property, but because the high-water marks established by it as it passed over the delta lands of Louisiana may serve as a guide in the design of the levee systems necessary for their reclamation. In past years it was the crevasse flood that the lowland farmer had to fear, but to-day the danger from a break in the river levee is so remote that no effort is made in the design of marsh land levees to protect against invasion by the Mississippi.

Considerable difference of opinion exists as to the best

methods of levee construction in the soft prairies. The construction of levees along the river front has indeed afforded data in abundance, but not often such as are applicable to marsh land work. For instance, while it is pretty generally conceded that a muck ditch is desirable to prevent seepage, complete removal of vegetation and muck from the site of the levee is not only unnecessary, but undesirable. The impervious character of levees built on a muck base is truly surprising. The material is so completely puddled as it is placed in the embankment that each dipperful bonds perfectly with the material previously deposited. There is undoubtedly a certain amount of seepage in all such levees, but the exact amount is difficult to determine. Observations taken on the Smithport tract at Lockport in 1909, and on the Willswood Plantation the same year, indicate that it is inconsiderable except at weak points in the levees and under especially adverse conditions. The observations referred to were taken in connection with the drainage investigations carried on by Prof. W. B. Gregory and the writer during 1909, under the direction of Mr. C. G. Elliott, of the United States Department of Agriculture.

In the levee construction on the Phillips Land Company's tract in Plaquemines Parish, a hydraulically placed base was put in for a considerable distance. To all appearances, this makes an excellent base, and should effectually shut off seepage, as the high velocity of discharge tears up the sod, cutting an ideal sod ditch.

The most useful field for the hydraulic ditch is in the construction of the interior reservoirs and the larger collecting canals. By a suitable arrangement of discharge pipes the waste material may easily be deposited at a distance of 50 ft. from the bank, the resulting waste bank being so low that it does not interfere with cultivation.

In the design of interior ditching systems, there is little uniformity among those engaged in reclamation work. Many conditions enter into the problem which affect the general layout of ditches, but in general it may be said that the ditch scheme which has been developed here in the sugar belt is pretty generally applicable to any reclamation project. The tendency now seems to be to increase the length of cuts between headland ditches to avoid all unnecessary waste of land and to permit the use of power plows, a recent innovation in this field. Too great a distance between headland ditches is objectionable, however, on account of the extremely low efficiency of the small field

laterals. This is rather a free use of the word "efficiency," but it refers to the useful work done, i. e., water discharged, for the hydraulic grade and radius supplied. It is necessary to collect the water rapidly into trunk canals so as to insure passage from the fields to the pumping plant on the least possible gradient and in the shortest time possible. This plan is often modified to good advantage on tracts having more or less natural slope towards the pumping plant.

The field laterals usually have a cross-sectional area of about $7\frac{1}{2}$ sq. ft., and are spaced about 104 ft. apart in the heavy river-front lands. Some of the new muck lands appear to be well drained with laterals spaced 800 ft. apart, but this spacing must be reduced as the land dries out and becomes more compact. With ditches spaced 104 ft. apart, the material excavated amounts to 180 cu. yd. per acre. Under ordinary plantation conditions, work of this kind can usually be done for less than 5 cents per cubic yard. Hand work on large reclamation projects would doubtless cost more, but there are now constructed ditching machines which can cut these ditches at a price which will enable them to compete with hand labor.

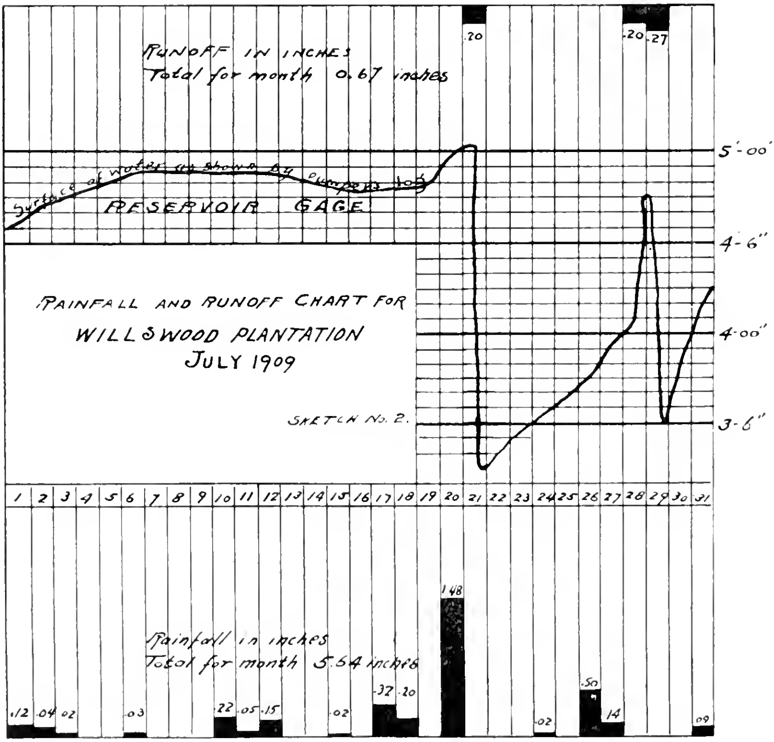
With the exception of the ridge lands along the Mississippi River and the various bayous, all the lands in this vicinity are so near sea level that artificial drainage must be resorted to in order that satisfactory drainage may be secured. This entails one or more pumping plants for each drainage unit. There are many members of this society who have had valuable experience with low-lift pumps, handling large volumes of water. The following points in regard to pumps and their operation have been introduced with the idea that a discussion by such members of the more vital points may be provoked rather than with the idea of presenting any new views:

On a new reclamation project, one of the most difficult questions that the engineer is called on to decide is the size and type of pumps to be installed, and of these two the size or capacity is the more difficult.

Plantations provided with pumps of a twenty-four hour capacity of approximately $1\frac{1}{2}$ in. are occasionally overflowed, while others are satisfactorily drained by plants of one half this capacity, the difference being due to unavoidable differences in slope and soil conditions.

Assuming for any case, a ditch system so arranged that the water may reach the pumps readily, the following factors will control the capacity of the pumping plant to be selected:

1. Area served.
2. Rainfall.
3. Storage capacity of canals and ditches.
4. Absorptive capacity of soil. This is controlled in turn by the physical make-up of the soil and also by the height at which the water table is maintained.
5. Humidity.
6. Temperature.
7. Sunlight.
8. Crop consumption.



Engineers have at times placed too much dependence on rainfall data in the estimates of probable run-off without giving proper attention to other important factors. The rainfall is such an obvious factor and so easily reducible to terms convenient to use that one is tempted to use it and go no further, but without a knowledge of other conditions it has little value in our work. This point is illustrated graphically by the accompanying sketch, No. 2, which shows conditions on the Willswood Plantation in

July, 1909. The preceding month was abnormally wet, the rainfall being double the mean monthly rainfall of 4.64, with a run-off of 50 per cent. of the rainfall. The month of July began with the soil well moistened by the rains of the previous month. An examination of the sketch will show that a rainfall exceeding $5\frac{1}{2}$ in., plus the seepage, necessitated the running of the pumping plant on only three days of the month. The total amount of water removed amounted to 0.67 in., less than 12 per cent. of the rainfall. This remarkable falling off in the proportion of run-off to rainfall was due to the fact that weather conditions and farming operations were generally favorable to a high rate of evaporation, and the heavy crop was probably drawing a maximum amount of water from the soil. From this it is easy to see that no empirical rule, based on rainfall alone, can be developed for the design of pumping stations. In spite of such excessive fluctuation in the relation between rainfall and run-off as indicated by the foregoing, we shall probably continue to base our calculations of water to be removed on the rainfall, and as the practice of expressing the latter in inches over the area affected has become fixed, it seems expedient to express run-off in the same terms. By the expression "1-in. run-off" is meant a volume of water which would cover the area under consideration one inch in depth. As most commercial ratings of pumps are expressed in gallons per minute, it has been found convenient to secure a constant for reducing readily the run-off in inches to gallons per minute. The constant used is 18.9 gal. per minute. This is equal to a run-off of one inch on one acre for a twenty-four hour period.

The months of greatest rainfall occur in midsummer, so that the work of pumping is somewhat relieved by weather favorable to evaporation. Many who are not acquainted with local conditions assume that it is not necessary to pump the reclaimed lands after one crop is removed until ready to put in another, but this idea is erroneous; in fact, it often occurs that the heaviest pumping is done during the winter months. If the water table were allowed to rise to the surface, and remain through two or three months, it would be impossible to get the land back into the physical condition suitable for crops.

Little information is available which will give to the engineer an idea of the number of days in a year when pumps must be operated, though one record of pumping operations was found which extended over a period of two years. The average rainfall for these two years was a little above the mean for this locality.

The average days pumped per month was 5.3, or 63.5 days per year. It is probable that this is somewhat above the average for that particular tract. This does not signify that the plant was operated 63.5 days, for on many days the pumps were operated for a very few hours.

In the consideration of possible flood conditions, the engineer seldom plans his pumps to carry off the water from record storms before any injury to crops may result. These maximum storms occur so seldom that the additional investment necessary to fully guard against them would not be justified by the advantage gained. These have been arbitrarily divided into three classes, those from 3 to 5 in. being the class of rains which we will assume can be easily handled by the pumping plant working full time under ordinary conditions.

The second class, 5 to 7 in., would compel running the plant at its maximum capacity and for full time. With favorable conditions, the pumps should handle the water from such rains before serious injury to the crops could occur. Rains exceeding 7 in. might result in injury to crops, the degree of injury depending much on others of the list of factors already mentioned.

The following statements of rainfall are based on the records of the United States Department of Agriculture. These records show that in the past twenty-one years we have had:

37 rains exceeding 3 inches.
16 rains exceeding 4 inches.
5 rains exceeding 5 inches.
2 rains exceeding 6 inches.
2 rains exceeding 7 inches.
2 rains exceeding 8 inches.
0 rains exceeding 9 inches.

Any formula which may be devised for the calculation of run-off from a given rain must take into account the possibilities of evaporation. This is a most inviting field for the student, but it is probable that the experimenter will bring out more useful data than the purely mathematical student. If a working formula is devised, it will doubtless make Kutter's formula look like a second-grade problem in addition. In spite of the obvious difficulties, such investigations should be instituted if any means can be devised for carrying them on. If we could once get a working basis, we should find a mine of valuable data at hand in the shape of records of the Weather Bureau, where are kept not only records of the rainfall, but also temperature records, humidity records, number of cloudy days each month, and much other

information of a like nature. Tabulations are made of the various records of the bureau, and these are made available in the most convenient form for the student or investigator. Such records, covering as they do a long term of years, will be invaluable in the studies which must be made before the relation of rainfall and run-off can be reduced to a concrete formula. If I am not mistaken, the rainfall records are practically continuous for over seventy years. Observations as to humidity, temperature, cloudy days, etc., have been taken continuously since 1871.

An almost endless discussion might be started over the most suitable type of pump. Any one engaged in reclamation work is made the target for the man who has (or thinks he has) a new idea for lifting water. Many of the suggestions are so absurd as to be very amusing.

To be applicable for use on drainage units of moderate size, a pump must fulfill the following requirements:

Low first cost.

Simplicity of construction and ease of operation by unskilled labor.

Not subject to delays through breakdowns or other causes.

Reasonably high efficiency at various heads.

Capacity for considerable overload at times of excessive floods.

Much can be said in favor of the drainage wheel which is so often found on the older sugar plantations. These were built to enormous sizes, but in spite of their apparent simplicity, they were not a cheap outfit. They show a good efficiency at the proper stage of water, but this efficiency drops rapidly with any considerable change of head. The economical lift for these wheels is often figured at one sixth the diameter of the wheel.

Some form of centrifugal pump has usually been selected for the newer plants in this vicinity. The efficiency of the best of these pumps under the varying heads is nearly constant, and they are capable of increasing their output over normal rating when necessary. Under emergency conditions, economy of operation may be disregarded as it is so seldom that such conditions arise that they would not justify the construction of a plant sufficiently large to handle the water of maximum storms by running at normal speed.

Many planters equip their pumping stations with two or three very large units of exactly the same pattern. Such duplication of machinery is preferred in order that repair parts for one pump may fit the other. It would seem as though the ad-

vantage to be gained by an assorted equipment would give better results. Take, for example, a pumping plant of about 60 000 gal. per minute capacity. This would require one 48-in. pump of the ordinary type, or two 36-in. pumps, or one 45-in. and one 18-in. It is true that a given capacity can be more economically secured by a few units of larger size rather than by a larger number of small units of the same total capacity, but there are too many chances for breakdowns to occur to make it wise to attempt to operate with only one pumping unit.

Even the highest grade centrifugal pumps that are now on the market fail to show a very high efficiency under the conditions that prevail in the local drainage plants. There are certain unavoidable losses in the pumps which are nearly the same for the low and for the moderate lifts. While pumps for irrigation works may be purchased with a guaranteed efficiency of 75 per cent., it is doubtful if this efficiency can be secured from any centrifugal pump now on the market when working against a static head of only 3 to 7 ft. A centrifugal pump especially designed to meet local conditions might be of lighter construction than is now made and with impeller blades of such shape as might be found to give the best results.

As to the power plant, it may be said that in small drainage units the simplest type of boiler and engine are preferable. In the larger units, more expert men will be placed in charge of the machinery, and a more elaborate type may be used to advantage. It is not economy, however, to install the most expensive engines and boilers, as the plant runs for such a short proportion of the time that the interest on the investment and depreciation would more than offset the advantages gained.

If it is true that the marsh lands of the Louisiana coast country can be reclaimed, the next generation will see a most wonderful change in this portion of the state. The effect will be far-reaching, for the benefits will fall to the city of New Orleans as well as to the surrounding country. In some ways the city now occupies a most unfavorable position, compelled as she is to draw from a distance for the most of her business. An estimate made by Mr. Edward Wisner some few years ago showed that only about five per cent. of the land within a radius of fifty miles of New Orleans was actually producing anything. A large proportion of the area drained by the Mississippi River may be said to be logically tributary to this port, but, to secure even a fair share of the export and import business, we must enter into active and sharp competition with the other ports of the country,

while the reclamation of these lands at our very door will add that much territory, which will, of necessity, be tributary to New Orleans, not only for its foreign trade, but for all the business which a producing section ordinarily brings to its metropolis.

DISCUSSION.

Mr. J. F. Coleman. — The subject of which this paper treats is one of very lively interest at this time, not only to the members of our Society, but to a large number of residents in Louisiana and to a considerable number of investors from other states, who by their investments in our marsh and swamp lands have acquired a commercial interest in the proper solution of the engineering problems in land reclamation.

Mr. Shaw has divided the lands requiring drainage into four types.

While it is unquestionably true that as engineers we are interested in each of these four types, it is also a fact that by reason of the present activities in this section our interest is more lively in the drainage of those lands which are subject to tidal overflow, and therefore it is to this type or these types of lands that this writer will address himself, and more particularly to those lands which belong in the class on which many of us are now at work and of which there are at the present time some two and one-quarter million acres within a radius of sixty miles of New Orleans.

These lands lie generally at an elevation of mean sea level, they are never dry and are often submerged by the lunar tides. Our occasional storms flood them to varying depths depending upon their proximity to or remoteness from the open waters of the Gulf, and depending also upon conditions of direction and force of wind storms, topographical peculiarities and other details not necessary or desirable to discuss at this time.

The reclamation and drainage of such lands expressed in simple terms consists in the construction of levees to exclude the tides, in the excavation of canals and ditches to deliver the run-off to the pumping station, and in the construction and operation of pumping plants with which to remove the run-off. Levees, canals, pumps — it all sounds very simple, and within a few years it all will be as simple as it sounds; but during these few years some of us are going to spend anxious moments while our judgment as to some of these items is being tried in the fire — or perhaps it would sound better to say, in the water.

Levees. — In the design of a given system we must among the first things determine the elevation to which our levees must be built. Mr. Shaw's paper informs us of the tidal elevation at the mouth of bayou Terre Bonne, September 20, 1909, 15 ft. It is manifest that had any area been reclaimed at that location at that time, its levees must have been overflowed and perhaps destroyed had they been of lesser height, and yet the cost of such levees as would protect against any such elevation would for the present at least be prohibitive.

Mr. Shaw mentions elevations of 8 ft. at Leesville on bayou LaFourche, $5\frac{1}{2}$ ft. at Grand Isle, 7 ft. at bayou LaLoutre, about 5 ft. at the mouth of the Atchafalaya, etc.

One of our problems therefore is "To what elevation shall our levee be built?" As we are wofully lacking in precise records of elevations of past storms at any given location, we must of necessity be driven to the "oldest inhabitants" for such information as we may derive from them, and because the lands we wish to reclaim are not habitable, these "inhabitants" are few in number and usually in no degree certain in the information they can convey.

Having determined by such means as we may the elevation of levees, we next must determine what cross-section (minimum) we shall provide in our levees, what shrinkage we shall provide for, and what amount of subsidence will probably take place. The minimum section will in great measure depend upon the conditions of exposure of the proposed levee; also upon the nature of the soil on which it rests and the material of which it is to be constructed. This "minimum" section will usually be where there is no necessity for a canal alongside; for in the latter case the excavations from the canal are generally more than ample for levee purposes. In the opinion of this writer this minimum section *may* sometimes, under exceptionally favorable circumstances, be as low as 4 ft. crown with $1\frac{1}{2}$ to 1 slopes; and in few instances will it be greater than 10 ft. crown with 2 to 1 slopes. The shrinkage is comparatively easy to determine, based on general experience in levee construction. The subsidence is a factor upon which we have comparatively few data and will depend upon the character of the foundation, weight imposed by the levee, etc. At the present time there is no information known to this writer which leads to certainty of conclusion on this point, and the only practical solution appears to be to exercise the best judgment in construction and then under maintenance to take care of any excess of subsidence by regrading so as to maintain the elevation determined upon.

Incidental to the levee construction problems are those of protection from wave wash on exposed places, protection from muskrat, crayfish, etc., which have to be considered to some extent in construction although they are really problems of maintenance.

Canals. — In designing the canals we first determine (at present more or less arbitrarily) the elevation to which we wish to reduce our " water table " at least in theory. We obtain such data as we may covering the soil formation and that of subsoil, which aids us in determining the maximum depth of our canal excavations and settles the question of wide shallow canals versus narrow deep canals. We study rainfall records, soil conditions, temperature, humidity and sunlight records; we try to arrive at some practical ideas as to the nature of the crops that may be planted so as to have fairly intelligent views of the probable general layout of field ditches and drains. If there be a slope to any of the lands within the area to be treated, this must also be considered. We finally deduce our conclusions as to the amount of reservoir capacity we must provide for, and the " run-off " which the ditches, laterals and canals must be capable of delivering to the pumps. It has thus far been the practice of this writer to reduce his conclusions as to " run-off " to be taken care of by the canals and ditches to terms of inches, or fractions of an inch, for the entire area per twenty-four hours. In order to provide something in the nature of a factor of safety, we usually design the canals to have a greater capacity of flow per twenty-four hours than the pumps, so as to add to the reservoir capacity and to provide against reduction of canal discharge which will naturally follow the growth of weeds and other plants along the canal banks. This, however, cannot always be done, for the reason that when the lands in part of the area to be treated have a well-defined slope, it is not well to precipitate the water from the high lands to the low lands too rapidly as it would cause overflow of the low lands. We also generally so design our canals that with the maximum service for which designed they will have a velocity of flow of about 2 ft. per second at point of delivery to the pump, permitting this velocity to gradually decrease to about $1\frac{1}{2}$ ft. per second at the extremities of the system when the distances to the extremities are comparatively great.

Pumps. — And then we enter upon the questions involved in the pumping station. As a civil engineer who tries to stay on his own side of the fence, this writer has never concerned himself

with the questions of design of pumping stations. It has been and is the practice in our office to determine to our own satisfaction the minimum and maximum elevation of water in the suction basin and the maximum and minimum elevation of water in the discharge basin, and then to prescribe that the pumping station shall be capable of delivering such a quantity of water per second from a given elevation to another given elevation with maximum efficiency of the plant, further requiring, however, that at reduced efficiences the plant shall be able to receive water from the minimum elevation in the suction basin and discharge it to the maximum elevation in the discharge basin. We allow the greatest latitude to bidders as to sizes of units in boilers, engines and pumps, and require them to submit all possible guaranties for each of them, as, for example, in boilers, as to amount of water to be evaporated per pound of coal of a given value in British thermal units; in engines, the horse-power to be developed under given steam pressures and with given steam consumption, etc.; and the efficiencies of the pumps. So that we may know in the form of guaranties just how much water will be delivered from a given elevation to another given elevation within a given time by a ton of coal. It then becomes a commercial proposition to estimate upon whether it is better to purchase the high-grade plant with low operating costs than the lower-grade plant with its higher operating costs.

Finally, when all of this has been done and the drainage system is completed, we are just in a position to begin to learn something about the district involved, which we would have been glad to know before starting the design, but which in the present state of the art we could not have known.

In the foregoing statement, it has been assumed that no other questions than engineering questions have to be considered. We are sometimes, however, confronted with other problems. Suppose, for instance, after having done all requisite work of survey and research, you had designed carefully and painstakingly what you honestly believed to be the most economical system which would satisfactorily reclaim and drain a given area, and that the estimate of cost when submitted to your principals was greater than they could afford or than they were willing to expend, and that you should be directed to so amend your plan as to reduce its cost to a certain fixed and stated sum. It would then be necessary for you to exercise your ingenuity and your best engineering skill and judgment to bring about this reduction in cost with the least sacrifice of efficiency. And of

course there are limits beyond which you could not go, even under such instructions. It might be better sometimes to decline to even attempt such reductions in plan than to risk the probability — or, you might say, certainty — of such failure in general results as would cause a pecuniary loss to your clients and a loss of reputation to yourself.

Nevertheless, these problems come before all of us sometimes, we might say frequently, and it is not always easy to know just when to draw the line. As time goes on, however, and as we do more and more of this character of work, the many now practically unknown factors will gradually become known to all of us. The United States Bureau of Drainage Investigations is rendering valuable assistance in collecting data from all sources and in every other way possible to it. The Louisiana Engineering Society in such papers as that now under discussion will without doubt contribute its share toward the solution of many of the problems; and one of these days, as a final result, the design of a reclamation and drainage system in Louisiana will be a routine matter which will present few if any uncertainties to the engineer.

It is not usually the province of the engineer to paint beautiful word-pictures. If it were, he could certainly paint one in describing the results to New Orleans and to southern Louisiana which will be achieved when the two and one-quarter million acres now the home of the muskrat, the frog and the alligator, not to mention the mosquito, will have been drained and rendered arable and habitable, for no other land under the sun can be richer and more fertile than this, and we can but faintly dream of the agricultural wealth it may be made to produce and the population it will amply sustain.

MR. A. M. SHAW. — In the discussion of the question of reservoir capacity to be provided for tracts that are artificially drained, it appears that there is quite a difference of opinion as to what should be considered as the available storage basin. It has been my custom, in calculating the reservoir supplied, to include that part of the canal prisms between the plane of surface of water as it is usually maintained and the plane coinciding in elevation with the lowest fields served; that is, the available storage lies between the stage of water as ordinarily carried in the canals and that stage which would be a menace to crops in the lower fields. While it is true that to allow the water level to rise to the ground level and remain at that level for a considerable length of time would injure or ruin the crops, an occasional

or even frequent rise to that level will not seriously injure ordinary farm crops provided the water level is restored to normal level within a few hours.

In stating the amount of reservoir capacity which they advocate, some engineers base their calculation on the volume of the entire canal prism, regardless of the height of water maintained, while others go to the other extreme and include only that portion of the canal lying between what they consider the two permissible extremes of water level, such as $1\frac{1}{2}$ ft. and 4 ft. below the level of the low fields.

The last plan seems to be the logical one, the only opportunity for a difference of opinion being the assumed permissible extremes. For the sake of uniformity, I would suggest that in our discussions we assume the maximum height to be at the level of the lowest fields. The minimum level cannot be so easily fixed, as it is controlled not only by the character of crops grown but by the nature of the soil, relative elevations of various portions of the territory served and other variables.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 1, 1911, for publication in a subsequent number of the JOURNAL.]

WATER RESOURCES OF THE STATE OF NEW YORK.

By Walter McCulloh, Consulting Engineer, New York State Water Supply Commission.

[Read before the Boston Society of Civil Engineers, February 15, 1911.]

With all other sections of the United States the people of New York State have a deep natural interest in the important economic problems now brought so forcibly to the attention of the American people through the agency of what has appropriately been termed "The Conservation Movement." That interest is properly manifested at this time because, in all probability, no state in the Union is invested with conditions so favorable and opportunities so promising for the early accomplishment of material progress in the practical conservation of one of her most valuable, if not the most valuable, natural resource. In New York State the surface water supply as a natural resource is second in value only to the land itself, which indeed owes its value largely to the existence of an abundant natural water supply. It must be conceded that the value of water for potable and domestic purposes cannot be estimated in dollars and cents, constituting as it does a necessity of life for which no substitute exists.

Aside from any such consideration as this, water is practically the only natural resource within the state for the development of power, that fundamental requisite to the prosperity and comfort of a civilized community. The lack of coal as a natural resource of the state is compensated for in a large measure by the fact that in addition to an abundant supply of water, the topography of a large portion of the state and the profiles of the rivers are naturally favorable for the establishment of hydraulic power development and the construction of storage reservoirs for the regulation of the flow of the streams.

The state has taken a notable step forward in the past five years by assuming certain regulative control over the disposition of her water resources and by the institution of a systematic investigation of them to determine the extent of the supply and of existing development and their uses and the possibilities for new developments and additional uses. Extensive studies have been made to ascertain the possibilities for water storage

within the state, the necessary complement to extensive water power developments.

In 1902, after a succession of disastrous floods in the state, the Water Storage Commission was created by an act of the legislature, and it was directed to make surveys and investigations to ascertain the causes of the floods on the various rivers and other streams of the state and to determine what, if anything, could be done to prevent such overflows and the great damage resulting therefrom. After a year's work that Commission made its report and recommended the construction of a system of storage reservoirs as the only practical method of flood prevention.

The next step in the development of the movement for water storage and stream-flow regulation was the creation of the River Improvement Commission by an act of the legislature in 1904. That Commission was invested with power to make preliminary surveys, maps, plans and estimates for the regulation of the flow of any stream, the restricted or unrestricted or irregular flow of which should be shown to be a menace to the public health and safety of the community. If the improvement of any specific stream appeared to be of sufficient importance and the legislature approved, the Commission was then authorized to carry out the project and to assess the cost thereof, according to the benefits received, upon the various municipalities and individual properties benefited. The working out of this plan has not been as satisfactory as was hoped for it when the River Improvement Act was passed.

The Water Supply Commission was created in 1905, — the primary object of its creation being to insure an equitable apportionment of the sources for public water supplies among the various municipalities and other civil divisions of the state. Since its creation, the Water Supply Commission has passed upon 95 water-supply applications involving a contemplated expenditure by the applicant municipalities of over $250 000 000. The most important of these cases is the enormous undertaking of the city of New York to acquire a new supply of water from the Catskill Mountains amounting to 500 000 000 gal. per day, to be delivered through a tunnel aqueduct 90 miles long. The cost of this project is estimated at $175 000 000 or more.

In 1906, the duties of the River Improvement Commission were transferred to the Water Supply Commission, and in 1907 the duties of this latter Commission were broadened to include the study of water storage and water powers on a large scale.

The Commission is now engaged in three distinct but closely related lines of work: (1) The apportionment of municipal water supplies, (2) the improvement of rivers for the protection of the public health and safety, and (3) the investigations of the water powers of the state and the formulation of a plan for their general development and improvement.

It is the work accomplished under this last heading that will receive our attention this evening as being most interesting to engineers.

The state of New York has an area of 50 000 square miles, and a population, according to the census of 1910, of 9 113 000. The value of the manufactured products in the year 1900 amounted to $2 179 000 000. The Empire State stands first among the states in manufacturing interests, in the capital invested, the number of persons employed, in wages paid, and in the products manufactured.

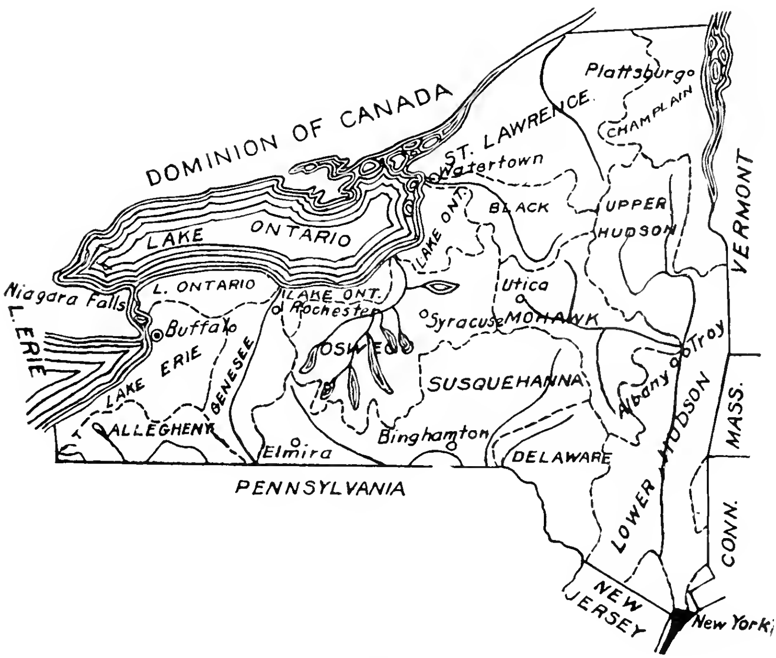


FIG. 1. WATERSHEDS.

The map Fig. 1 shows the principal watersheds of the state — those to the north and west draining into lakes Erie and Ontario and the St. Lawrence River, those to the east draining into Lake Champlain and the Hudson River, and those to the

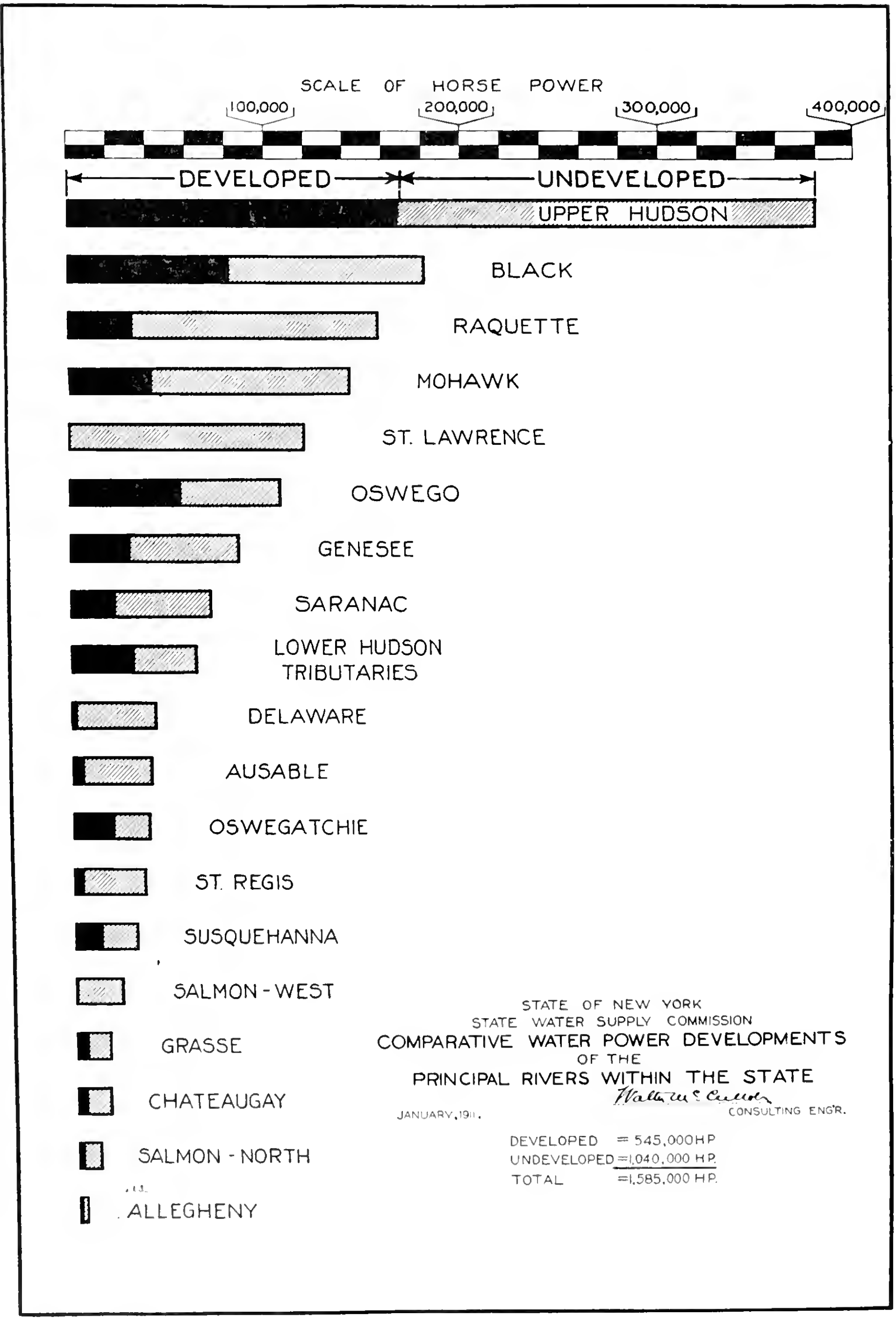

SCALE OF HORSE POWER
100,000
200,000
300,000
400,000
DEVELOPED
UNDEVELOPED
UPPER HUDSON
BLACK
RAQUETTE
MOHAWK
ST. LAWRENCE
OSWEGO
GENESEE
SARANAC
LOWER HUDSON TRIBUTARIES
DELAWARE
AUSABLE
OSWEGATCHIE
ST. REGIS
SUSQUEHANNA
SALMON - WEST
GRASSE
CHATEAUGAY
SALMON - NORTH
ALLEGHENY
STATE OF NEW YORK
STATE WATER SUPPLY COMMISSION
COMPARATIVE WATER POWER DEVELOPMENTS
OF THE
PRINCIPAL RIVERS WITHIN THE STATE
JANUARY, 1911.
CONSULTING ENG'R.
DEVELOPED = 545,000 HP
UNDEVELOPED = 1,040,000 H.P.
TOTAL = 1,585,000 H.P.

FIG. 2.

south and southwest draining into the interstate streams, the Delaware, Susquehanna and Allegheny rivers. The state has great geographical advantages for water storage and water-power development. The Adirondack region, in the northeastern portion of the state, is the most prolific water-producing section we have. The mountains are largely covered with forests, and in the valleys are numerous lakes out of which flow the power streams to the northwest, northeast and to the south.

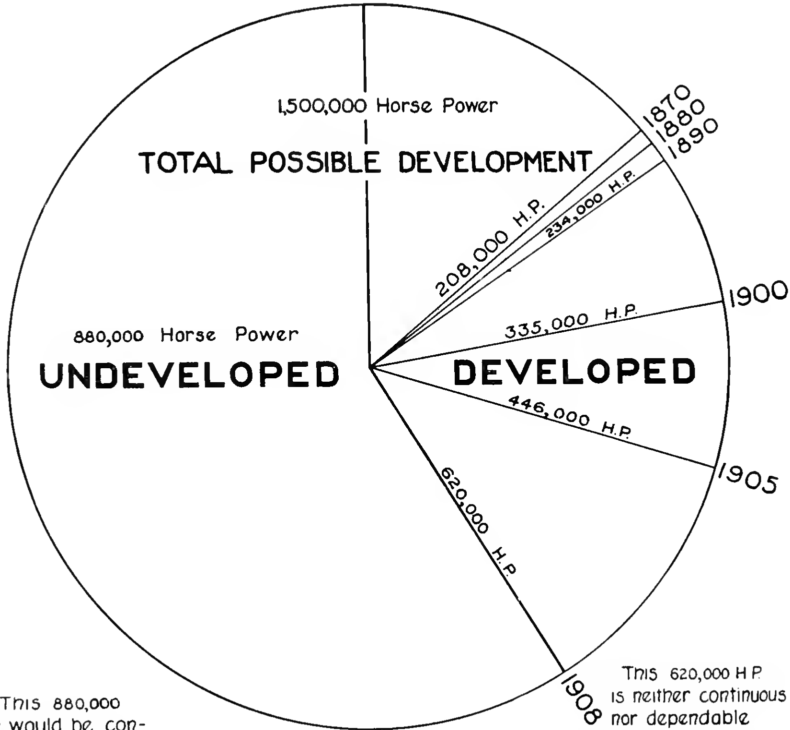
In this address we will consider only four of the large streams of the state, namely, the Niagara, Genesee, Hudson and Raquette rivers.

Coöperative Work.

When the state undertook the investigations for water storage and power development, difficulty was experienced in getting reliable data as to rainfall in certain sections of the mountainous country, and reliable stream flow records on the principal power streams. A coöperative arrangement was entered into between the State Water Supply Commission and the United States Geological Survey in 1907, by which the federal engineers have conducted the operations of stream gaging and rainfall observations, while the state has paid the major portion of the expense of such investigations, and the work has been done under the supervision of the engineers of the Water Supply Commission. This arrangement has proved very satisfactory, as the results of the work have clearly shown.

Water-Power Developments.

The chart Fig. 2 shows graphically the proportion of developed and undeveloped water power on the main streams, the Hudson River being the greatest power stream, exclusive of the Niagara and St. Lawrence rivers, which are international boundary streams and which cannot be considered as distinctively New York state power streams. The Hudson River has a possibility with water storage developed of 380 000 h.p., while only 185 000 h.p. has been developed up to the present time. The Black River stands second, with a possibility of 182 000 h.p. and a development of a little over 90 000 h.p. The St. Lawrence River on the chart indicates little or no development, and a limited possibility, but it refers only to that portion of the St. Lawrence River which is wholly within the borders of the state of New York and over which the state has entire jurisdiction as



This 880,000 H.P would be continuous 24 hour 7 day dependable water power without any auxiliary

Above figures are exclusive of International Streams; Niagara and St. Lawrence Rivers.

This 620,000 H.P is neither continuous nor dependable throughout the year. The deficiency is partially provided for by a considerable use of 124,000 H.P steam auxiliary.

STATE WATER SUPPLY COMMISSION
OF
NEW YORK
GROWTH AND PRESENT DEVELOPMENT
OF
WATER POWER IN N.Y. STATE
COMPARED WITH
POSSIBLE DEVELOPMENT
BY MEANS OF
STATE WATER STORAGE RESERVOIRS.

JANUARY, 1910.

Walter McCulloh
CONSULTING ENGINEER.

FIG. 3.

regards the water power. Were the total power of the St. Lawrence possible of development, it would probably exceed 1 000 000 h.p., but no development which contemplates the use of the whole or a large portion of the stream at any point can be undertaken without the consent of both the United States and Canada.

In 1908 a complete water-power census was taken, including all of the power developments of 100 h.p. and over, and some power developments as small as 25 h.p. This census developed the fact that there was 620 000 water h.p. developed and in actual use in the state in that year, and that in addition steam auxiliary plants with a total power possibility of 124 000 h.p. had been installed to partially meet the deficiency in power during low-water periods on the various streams. Fig. 3 gives at a glance the situation as developed by the power census of 1908. In addition to the census, a study was made of all the power possibilities on the principal streams, and it was determined that with a comprehensive system of water storage reservoirs there was a total water-power possibility of 1 500 000 h.p. It is thus seen that 880 000 h.p. was going to waste in 1908. Since that date several new developments and improvements on some of the older developments have been made, so as to save a portion of this waste, and yet the possibilities of the state to-day are less than one half developed. It is estimated that the value to the commercial interests of the state of New York of this wasted power amounts to $17 600 000 annually.

According to the figures given in the United States census in 1900, there is a possible total water-power development in the United States of 5 300 000 h.p. New York stands first in the list, with 1 500 000 h.p.; California next, with 446 000 h.p.; while Massachusetts stands higher than either of these two states in the ratio of developed water power to the total power possibilities.

Niagara River.

The Niagara River, having the inexhaustible supply of the Great Lakes behind it, is obviously in no need of storage works. It is only necessary to build headrace and tailrace works in order to take advantage of the power possibilities at Niagara Falls.

The two great power developments at Niagara Falls are the largest in the state, having an aggregate installation of 205 000 h.p., with an actual daily output varying from 160 000 to 180 000 h.p. A treaty made between the United States and Canada for control of the water from Niagara Falls permits a diversion of

56 000 cu. ft. of water per second, of which 20 000 cu. ft. per second is allowed to the power companies in New York State and 36 000 cu. ft. per second allowed to those in Canada.

The Niagara Hydraulic Power Company is the oldest of the present power developments at Niagara Falls, and takes its water from the upper river through an open canal passing through the city to the top of the bluff 2 000 ft. below the American Falls, where the water is led into a large forebay out of which it is distributed to the various developments strung along the bluff. Some of these developments are utilizing less than 100 ft. of the available fall, while the modern plants are taking full advantage of the total head of 210 ft. When this development was conceived many years ago there were no turbine wheels capable of working under a greater head than from 40 to 50 ft. Therefore, it was considered impracticable to use the full available head, which accounts for the numerous points of discharge from the mills at various heights from the top of the bluff to the lower river level. When the Niagara Falls Power Company began its enormous development in 1890, hydro-electric developments in large units and electrical transmission of power was in its infancy, but since that day marvelous advances have been made and the Hydraulic Power Company has practically remodeled and enlarged its entire plant, bringing it up to date in many respects.

The Niagara Falls Power Company began a modern development in 1900 consisting of a deep wheel pit near the bank of the upper river in which are installed the penstocks and turbine wheels, and from which the tail water is led to the lower river through a tunnel 7 000 ft. in length. In 1899 a second plant was undertaken by the Niagara Falls Power Company, and completed in 1904, making a total installation in the two power houses of 105 000 h.p. The dynamos in these two power houses work under heads varying from 130 to 160 ft., and generate 5 000 h.p. each.

Need of Regulation by Storage.

In determining the mean annual dependable rainfall in the state, it has been found necessary to examine a great many records, some of them extending back to 1829, and to analyze these records, determine their reliability or unreliability, and to coördinate them with the records of the nearest surrounding stations. From a complete analysis and coördination of these precipitation records, the map Fig. 4 has been prepared. The

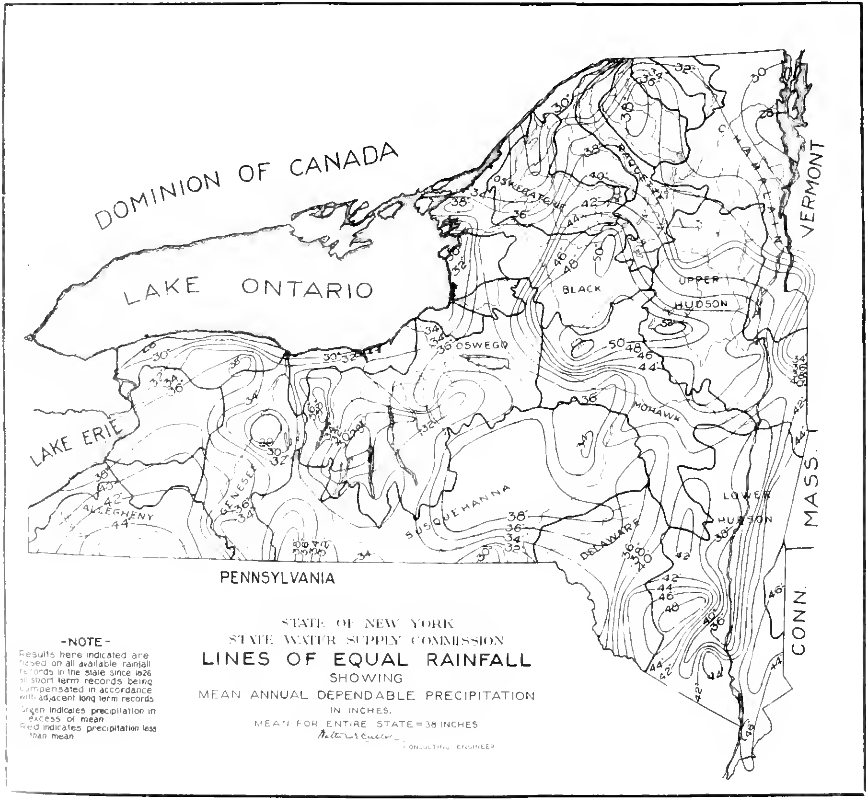

DOMINION OF CANADA
LAKE ONTARIO
LAKE ERIE
VERMONT
MASS.
CONN.
PENNSYLVANIA
OSWEGATCHIE
RAQUETTE
BLACK
UPPER HUDSON
OSWEGO
MOHAWK
GENESEE
ALLEGHENY
SUSQUEHANNA
DELAWARE
LOWER HUDSON
STATE OF NEW YORK
STATE WATER SUPPLY COMMISSION
LINES OF EQUAL RAINFALL
SHOWING
MEAN ANNUAL DEPENDABLE PRECIPITATION
IN INCHES.
MEAN FOR ENTIRE STATE = 38 INCHES
CONSULTING ENGINEER
-NOTE-
Results here indicated are based on all available rainfall records in the state since 1826 all short term records being compensated in accordance with adjacent long term records
Green indicates precipitation in excess of mean
Red indicates precipitation less than mean

FIG. 4

mean annual dependable rainfall is 38 in. and the range from lowest to highest is from 26 in. to 52 in.

The natural fluctuations in the flow of the streams of the state are vividly illustrated by the hydrographs on Fig. 5. All three of them show a marked contrast between the wet and dry seasons. The Hudson River, having its source in the Adirondack Mountains, has a partial regulation from the forests and natural lakes tending to reduce the severity of the floods. There is, however, inadequate natural storage for relief in the summer season when the power interests on the stream suffer greatly

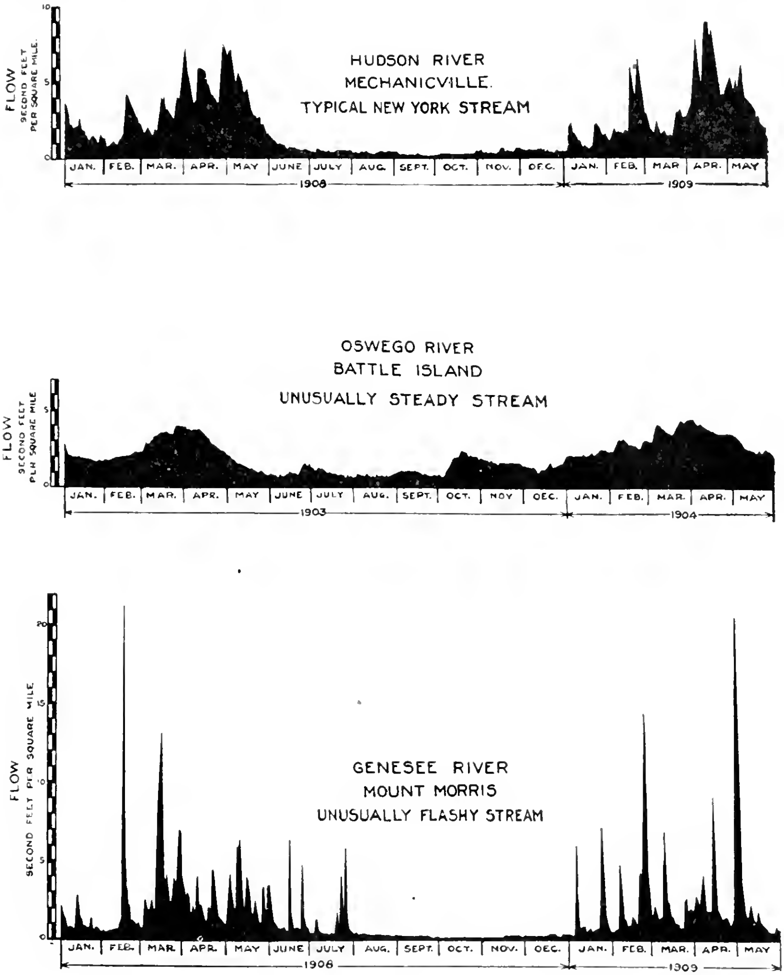


FIG. 5. HYDROGRAPHS SHOWING NATURAL FLUCTUATIONS OF FLOW OF NEW YORK STATE STREAMS.

from the lack of water. The Oswego River has a material natural regulation due to the storage on the so-called Finger Lakes — lakes Cayuga, Seneca, Keuka, Canandaigua, Oneida and others. The hydrograph of this stream shows less severity of flood in the wet seasons, and a better summer regulation than either of the other two streams. The Genesee River is the most flashy of any in the state. The rise and fall of the river is very rapid, and the floods come in a sharp wave, rising from the normal to maximum flood discharge within twelve to twenty hours and receding from the peak almost as rapidly as they rose. The watershed of the Genesee River is steep, almost entirely cleared of forests, and the land is used for pasturage or is under cultivation. The waters run off of this watershed with little or nothing to retard the sharpness of the discharge.

On the Raquette River at Hannawa Falls, a power development calculated to produce 13 000 h.p. has proved a financial failure owing to the inability to develop more than from 3 000 to 4 000 h.p. during the driest month of the year. The Genesee River at Rochester shows an equally marked variation between the flood and dry periods, the discharge at this point varying from 200 cu. ft. per second in September to 54 000 cu. ft. per second at times in March and April. The Genesee Falls in Rochester have been fully developed and the demand for power is great, but in order to operate the plants and meet the demand for power at least $200 000 worth of coal is burned annually to make up the deficiency in water power, while sufficient water runs to waste every spring to more than cover the shortage of the summer time.

Genesee River.

To correct the great variations in the flow of the Genesee River and to eliminate the damage caused annually by floods and the shortage of water in the summer time, it is proposed to build an enormous reservoir above the Portage Falls a little south of the center of the watershed. At this point the Genesee River has cut a deep gorge in the limestone and shale, and flows north over a succession of falls in Letchworth Park, where in a distance of three miles the fall is nearly 400 ft. The watershed above the proposed Portage dam is 1 024 sq. miles, and the discharge of the river at this point varies from 98 cu. ft. per second to 30 000 cu. ft. per second. Fig. 6 is a view of the middle and upper Portage Falls during a flood in 1909 when the discharge was 30 000 cu. ft. per second.

FIG. 6. MIDDLE AND UPPER PORTAGE FALLS.

FIG 11. RAQUETTE RIVER — HEAD OF RAQUETTE POND. (See page 150).
This territory would be cleared and submerged if proposed dam is built.

Fig. 7. Genesee River. — Avon Highway, May 3, 1909.
This condition prevailed for about three days.

The dam which it is proposed to build at Portage is designed to be 800 ft. in length, with a spillway dam also 800 ft. in length extending along the side of the steep gorge at right angles to the main dam. The height of the masonry dam will be 152 ft. at the center section, and the bottom width at this point will be 115 ft. The top is 29 ft. wide. The masonry will be cyclopean, with concrete faces dressed to harmonize with the walls of the gorge into which the dam abuts. Ports are to be provided in the spillway dam for the control of the peak of floods. The capacity of the reservoir above the bottom level of the ports is 6 000 000 000 cu. ft., and it is designed to retain this portion of the reservoir for flood control. Gates are also to be provided in the dam capable of discharging 3 000 cu. ft. per second. When the floods come, the waters spread out over the surface of the reservoir, the ports begin to discharge and will continuously discharge only so much of the flood as can be kept within the banks of the river as it flows through the flat valley below the dam, between Mt. Morris and Rochester. The reservoir behind the Portage Dam will be 15 miles in length, and an average of one mile wide. The depth of water will be 70 ft. on the average, and the total capacity 19 000 000 000 cu. ft.

Under existing conditions the floods rush through the Genesee gorge unrestrained and spread out over a large territory of one of the most fertile valleys in the state, flooding from 20 000 to 30 000 acres of farm land every year, and in some years this territory is flooded in the spring and autumn. The view in Fig. 7 is typical of the conditions in the Genesee Valley below Mt. Morris during a flood of ordinary severity.

Immediately below the Portage Reservoir there is a power possibility of 30 000 h.p under a head varying from 360 to 450 ft., depending upon the amount of depletion in the reservoir. To accomplish this development, it would be necessary to construct a pressure tunnel $1\frac{1}{4}$ miles in length under the hill forming the northern rim of the reservoir, and ending at a point below the lower Portage Falls. The pressure tunnel plan is advisable for two reasons: (1) To take full advantage of the total fall, and (2) to avoid encroaching upon the property comprising the Letchworth Park, which is now a state park, having been presented to the state of New York by William P. Letchworth with the condition that the property should be used for park purposes only.

In addition to the power possibility at the dam, the Portage Reservoir would greatly add to the efficiency of the water-power

development at Rochester. In order to illustrate just what would be the benefits to the water-power plants at Rochester, a diagram was constructed of which the left half showed the river under present conditions and the right half illustrated the beneficial effect upon the power developments by a uniform discharge from the Portage Reservoir. This chart was based upon the assumption of an ideal regulation for the benefit of a power development at Portage with incidental regulation at Rochester, which arrangement has seemed to the engineers of the Water Supply Commission to be the most practical basis upon which to consider the construction of the Portage Reservoir. With 30 000 h.p. being developed below the Portage Reservoir, and the power plants in Rochester taking advantage of the increased regulated flow, they would be able to run continuously all the year with 17 500 water h.p., and if they desired to continue the use of their steam auxiliary plant, 29 000 h.p. could be continuously developed. There were many interesting points illustrated by this diagram which we have not time to explain here, but a full explanation of these charts and the conclusions drawn from them are shown in the fourth annual report of the State Water Supply Commission at pages 323 to 325.

Since the preparation of the hydrographs in 1908, a new method of demonstrating the power betterments by storage has been devised which we call the "power-percentage of time curve." In constructing the curves shown on this diagram, the first to be determined was the natural flow of the river. For this purpose the monthly discharges of the river shown by the stream flow records available were arranged in a table in the order of their magnitude. From this table the average percentage of time during which a given amount of horse power could have been developed from the natural flow of the stream was computed. Using the result thus obtained (the percentage of time) for an abscissa, and the corresponding amount of horse-power possible of development as an ordinate, a point was determined and plotted. A succession of points were plotted for various horse-power developments, and through this succession of points the curve marked "natural flow of the river" was drawn. To determine the regulated flow curve, the existence of a storage reservoir and the practicable utilization of its waters was assumed. The power value of the regulated stream was then determined in a similar manner to the determination of the natural flow of the river, and a succession of points plotted through

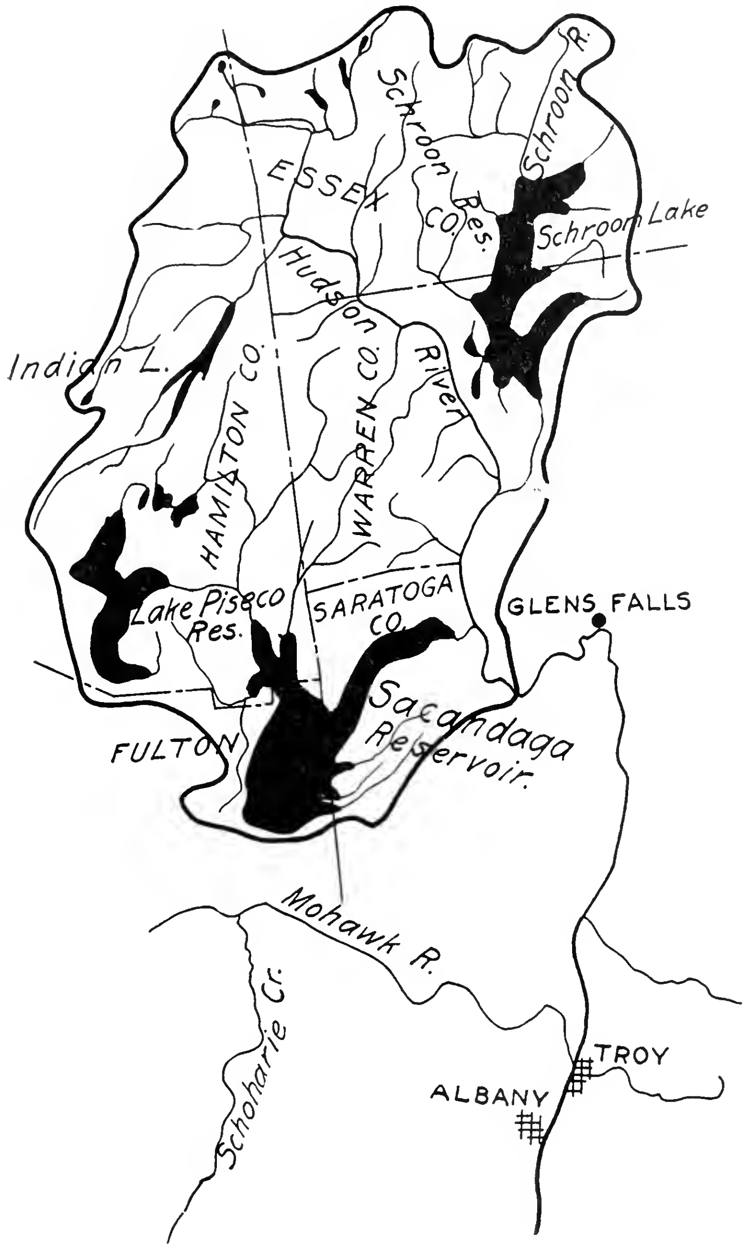


FIG. 9. HUDSON RIVER WATERSHED

which the "regulated flow of river curve" was drawn. These curves show the percentage of time during which any desired amount of horse-power can be developed at the point on the

stream to which the diagram refers; also what amount of power could be developed were the stream to be regulated by the construction of a storage reservoir on the upper watershed of the stream. For example: Fig. 8 shows the conditions at the existing power plants in the city of Rochester, from which we find that the present hydraulic installation of 29 200 h.p. can be operated with water from the natural flow of the river for only 59 per cent. of the time in each year. This is determined by the point on the "natural flow of the river curve" at the intersection with the horizontal line (equal to 29 220 h.p.) and reading vertically below this point approximately 59 per cent. of time is found. In a similar manner it may be noted that with the regulated flow of the stream this same installation could be operated with water for 85 per cent. of the time. The power increase from stored water is represented by the dark blue area which when integrated shows a value of 5 760 h.p. years, or an equivalent of 5 760 h.p. developed continuously for one year. After regulation only 390 h.p. years per annum would have to be supplied by an auxiliary plant. This latter method of illustrating the benefits to power plants seems to us to be more reasonable and accurate.

Hudson River.

The watershed of the Hudson River above Troy contains 8 100 square miles and the mean annual rainfall over this area is 43 in., the highest being 52 in. and the lowest 38 in. The discharge of the river at Mechanicville varies from 700 cu. ft. per second to 70 000 cu. ft. per second.

It is estimated that to completely control the flood discharges on the Hudson River would require a system of storage reservoirs with a combined capacity of 120 billion cu. ft. Surveys have been made and reservoir sites located with a total possible storage capacity of 61 billion cu. ft. The watershed map of the Hudson (Fig. 9) shows the location of some of the reservoirs which have been favorably considered and surveyed. The water-power plants on the Hudson River are capable of a total output of 170 000 h.p. at the twenty-eight developed sites between Troy and Corinth. These plants utilize 380 ft. of fall, and when the flow of water in the river is sufficient to run the mills, the average output is 117 000 h.p. The average low-water possibility is about 60 000 h.p., and on some occasions it has dropped as low as 25 000 h.p. for a period of from two to three days.

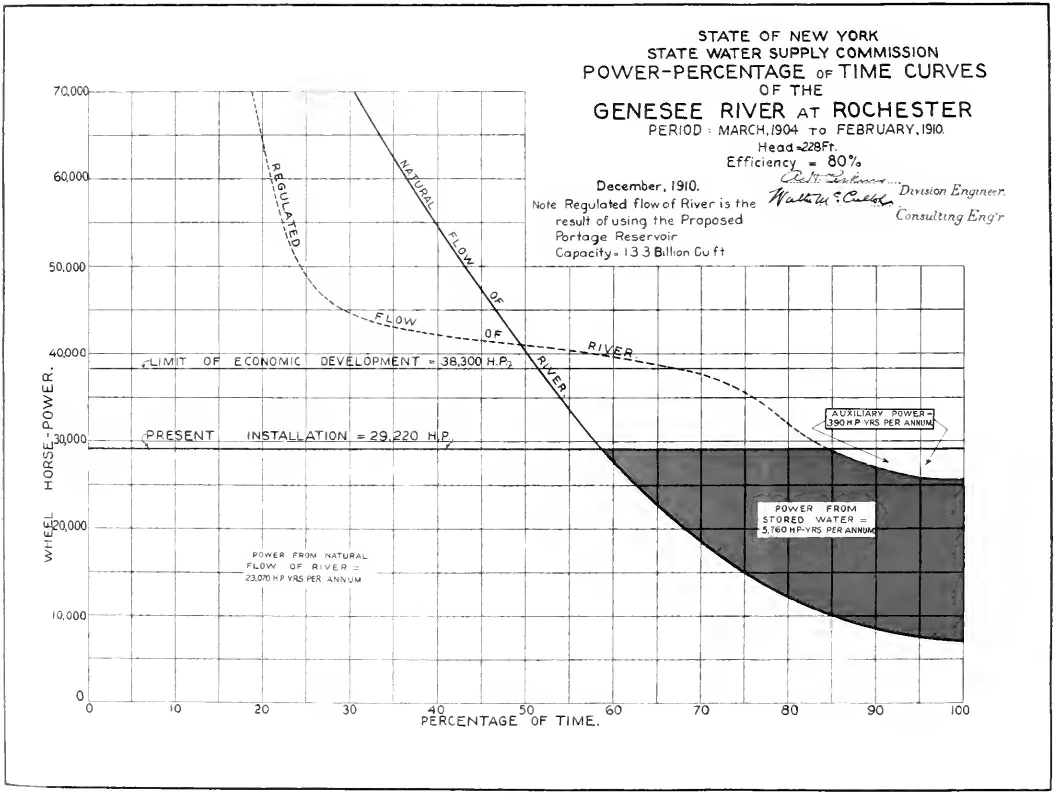

STATE OF NEW YORK
STATE WATER SUPPLY COMMISSION
POWER-PERCENTAGE OF TIME CURVES
OF THE
GENESEE RIVER AT ROCHESTER
PERIOD: MARCH, 1904 TO FEBRUARY, 1910.
Head = 228 Ft.
Efficiency = 80%
December, 1910.
Division Engineer.
Walter McCulloh
Consulting Eng'r
Note Regulated flow of River is the result of using the Proposed Portage Reservoir Capacity = 13.3 Billion Cu ft
REGULATED FLOW OF RIVER
NATURAL FLOW OF RIVER
LIMIT OF ECONOMIC DEVELOPMENT = 38,300 H.P.
PRESENT INSTALLATION = 29,220 H.P.
AUXILIARY POWER = 390 H.P. YRS PER ANNUM
POWER FROM STORED WATER = 5,760 HP-YRS PER ANNUM
POWER FROM NATURAL FLOW OF RIVER = 23,070 H.P. YRS PER ANNUM
WHEEL HORSE-POWER.
PERCENTAGE OF TIME.
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
10
20
30
40
50
60
70
80
90
100

Fig. 8.

I.

si
c(
st
st
in
th
w
o
"
h
th
si
th
8;
re
a
v(
y(
pl
pl

8
is
di
p(

o1
w
m
ca
(F
b(
pl
17
a1
flo
ou
al
as

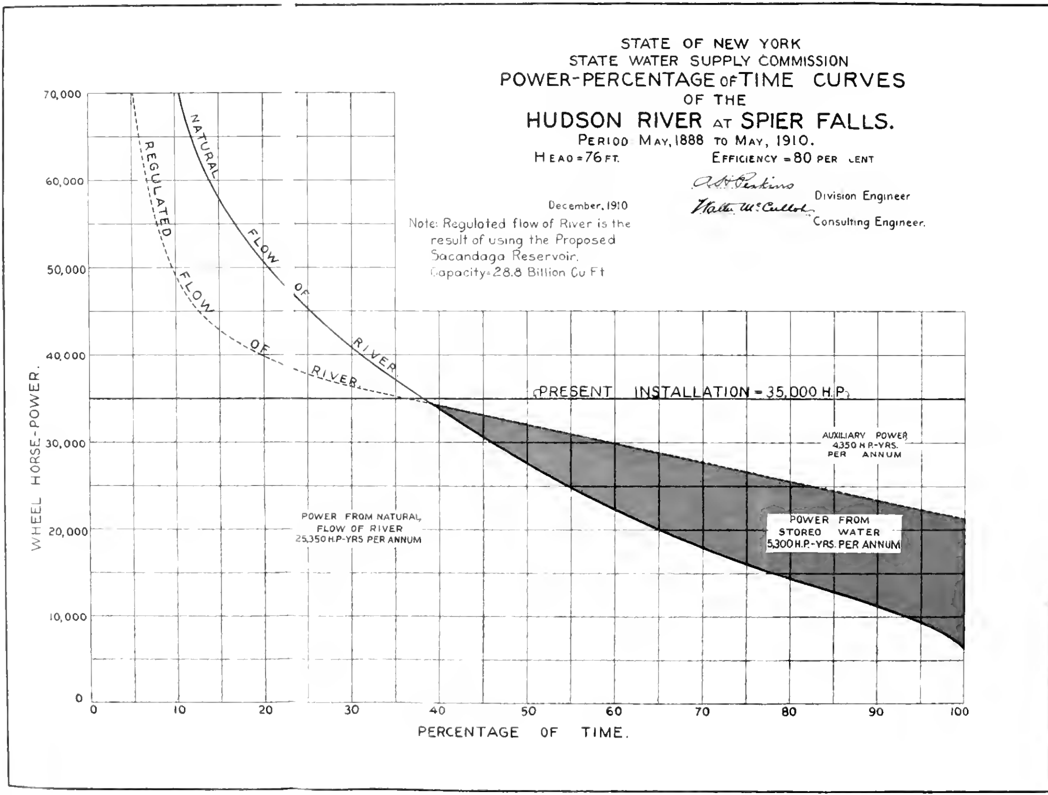

STATE OF NEW YORK
STATE WATER SUPPLY COMMISSION
POWER-PERCENTAGE OF TIME CURVES
OF THE
HUDSON RIVER AT SPIER FALLS.
PERIOD MAY, 1888 TO MAY, 1910.
HEAD = 76 FT.
EFFICIENCY = 80 PER CENT
Division Engineer
Consulting Engineer.
December, 1910
Note: Regulated flow of River is the result of using the Proposed Sacandaga Reservoir. Capacity = 28.8 Billion Cu Ft
NATURAL FLOW OF RIVER
REGULATED FLOW OF RIVER
PRESENT INSTALLATION = 35,000 H.P.
AUXILIARY POWER 4350 H.P.-YRS. PER ANNUM
POWER FROM NATURAL FLOW OF RIVER 25,350 H.P-YRS PER ANNUM
POWER FROM STORED WATER 5,300 H.P.-YRS. PER ANNUM
WHEEL HORSE-POWER.
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0
10
20
30
40
50
60
70
80
90
100
PERCENTAGE OF TIME.

FIG. 10.

Sacandaga River Project.

The Sacandaga River is the principal tributary of the Hudson above the Mohawk River, and a reservoir on this stream is considered to be the most feasible as the first unit of storage development in the Hudson River system. This reservoir would be created by the erection of an earth dam across the Sacandaga River at the hamlet of Conklingville. The dam as designed will be 1 200 ft. long, 95 ft. high, have a top width of 40 ft. and a bottom width at the greatest section of about 500 ft. It is proposed to construct this dam by the hydraulic sluicing method. The dam will impound 32 000 000 000 cu. ft. of water, of which only 29 000 000 000 cu. ft. will be available for stream-flow regulation. The lake created will be 30 miles in length, and have a surface area equal to that of Lake George, — 42 square miles. The cost of the reservoir without power developed will be $4 661-000. The regulated flow of the Hudson during the summer months will be 1 900 cu. ft. per second, at the minimum, and also add to the power plants on the river about 85 000 h.p. annually.

The chart Fig. 10 illustrates the power value of regulation from the Sacandaga Reservoir by the "power percentage of time curve" method, as applied to the development at Spier Falls. The hydro-electric installation at this place is 35 000 h.p., which can be operated only 38 per cent. of the time under present conditions. The Sacandaga Reservoir would add 5 300 h.p. years per annum, but in order to run the plant continuously 4 350 h.p. years per annum would be required from some auxiliary power.

Schroon River Project.

The second largest project in the Hudson River watershed is at Schroon Lake, and contemplates the erection of a masonry and earth dam across the Schroon River at Tumblehead Falls. The dam as designed will be 600 ft. long and 70 ft. high, with a masonry spillway 400 ft. long. The dam will impound 16 billion cu. ft. of water and create a lake with a surface area of 15 700 acres, covering three natural lakes (Schroon, Brant and Paradox) to a depth of about 20 ft. The estimated cost of this reservoir is $2 000 000, and it will assure a minimum flow when added to the Sacandaga Reservoir of 2 850 cu. ft. per second, and will add 50 000 h.p. annually to the Hudson River plants.

Raquette River.

The Raquette River rises in the Adirondack Mountains and flows westerly and northwesterly into the St. Lawrence River. There are large power possibilities on this stream between Tupper Lake and the St. Lawrence River, a distance of 75 miles, and although some of them have been fully developed, the larger portion of the possibilities still go unused.

In 1869 a dam was built with the consent of the state at Settingpole Rapids, below the outlet of Tupper Lake. The dam was intended for lumbering purposes, and the people who built it had so little regard for anything other than getting sufficient water to float their logs that no attempt was made to clear the reservoir site. The impounded water flowed a large area of forest land, killed all the trees, and turned a beautiful valley into a scene of desolation. The view in Fig. 11 illustrates the result. It was claimed that the cost of clearing this reservoir site in 1869 would have been greater than the benefit to be derived by the lumbermen from the erection of the dam.

It is estimated that the flow of the Raquette River can be controlled by the construction of reservoirs having a total storage capacity of about 19 billion cu. ft. The largest of these reservoirs would include Big Tupper Lake, and a territory some 15 miles in length above the outlet of Tupper Lake, and would have a storage capacity of 15 billion cu. ft. The project would cost $2 250 000 and would add about 33 000 h.p. to the plants already erected on the stream and would make possible an additional development of 110 000 h.p. annually.

In the vicinity of the proposed Tupper Lake dam also great damage was done by the erection of the Settingpole Rapids dam, creating a reservoir without properly removing the trees. This section of stump land covers an area of nearly four square miles, and were the Tupper Lake Reservoir to be constructed, the entire area would be covered with water and the unsightly conditions completely removed. It is unsightly conditions like these which have created a strong sentiment throughout the state against the construction of reservoirs in the Adirondack region. Persons who have viewed this situation form the erroneous opinion that all reservoirs would result in practically the same unsightly surroundings.

If, instead of building a dam at Tupper Lake Village, one could be built above the outlet of Big Tupper Lake, a reservoir of 11.4 billion cu. ft. capacity could be constructed at a cost of

about $1 200 000. This site is known as the Ox Bow. The hills at this point are much closer together than at the lower dam site, but no rock foundation has been discovered, which fact necessitates the construction of an earth dam instead of a masonry dam.

One of the large developed powers on the Raquette River below these proposed reservoirs is at Piercefield, where the International Paper Company operates a large pulp and paper mill. Great loss is entailed upon the paper company by the necessity of shutting down the mills in the low water season, and a loss is also sustained by the operatives through the loss of employment and a consequent cutting off of their source of income.

A large undeveloped power exists at Colton Falls about 30 miles below Piercefield and 15 miles above Potsdam. The river makes a long curve to the north as it flows over a succession of falls and rapids, falling 260 ft. in less than one mile. The development suggested at this site is an open canal across the chord of the curve of the river, with a forebay on the top of the hill and long penstocks to a power house in the lower gorge. This power house would be 4 200 ft. from the headgates at the top of the upper falls, and with the regulated flow of the stream the proposed installation would produce 30 000 h.p. years. The estimated cost of the Colton Falls development for 30 000 h.p., without taking into consideration the construction of reservoirs in the upper watershed, is $2 815 000.

Under present conditions the flow of the river at Colton Falls varies from 300 cu. ft. per second in the low-water period to 18 000 cu. ft. per second during the flood periods. The lakes and forests in the watershed have a regulating effect upon the natural flow of the stream but do not afford adequate storage.

State Lands Problem.

The State Water Supply Commission has made numerous surveys for reservoirs in the Adirondack region, as this mountainous country is obviously the most productive of opportunities for water-storage and water-power development, but it has been found that lands now owned by the state of New York, and forming a part of the Adirondack forest preserve, are situated in many of the most attractive reservoir sites. There is a constitutional prohibition against the use of any of the state lands in the forest preserve for any purpose whatsoever other than park

purposes, and they must be retained as wild forest lands. This section of the constitution was originally designed to protect the state forest lands against timber thieves, and the misuse of the lands by private interests, but it seems to many that the time has now come when the constitution should be amended and the state be permitted to utilize her lands in the forest preserve to the best advantage for all of the people of the state.

Many of the reservoir sites contain land that is swampy and inaccessible for pleasure purposes, and are covered more or less with dead trees and swamp brush, which are unattractive and unenjoyable to the people who visit the Adirondack region during the summer months. If these large waste areas could be converted into artificial lakes, we hold that it would be a benefit to the forest and at the same time would be a source of revenue to the state, when the water is used properly under state ownership and control, of far greater value than any imaginary damage that might be done to the state park, and would more than compensate the people of the state for the withdrawal of a comparatively few acres of land in the park for reservoir purposes.

A comparison of these areas is of interest: The total area of the Adirondack park is 3 313 000 acres, of which the state now owns less than one half. The total amount of land now owned by the state which would be required for the most complete system of storage reservoirs in the Adirondack park would not exceed 55 000 acres, which amount is only 1.75 per cent. of the total area of the Adirondack park. The good timber land involved in all of the reservoirs is but one third of one per cent. of the total area of the Adirondack park. These figures clearly demonstrate that were it to be conceded for the sake of argument that reservoirs in the Adirondack Park would be a detriment, or deprive the public of the enjoyment of a portion of the land, the amount so used would be of trivial consequence when compared with the total amount of forest remaining.

The State Water Supply Commission by its three years of surveys and investigations has discovered many interesting situations with regard to water storage and water power. Reports and recommendations have been made to the legislature by the Commission, and a campaign of education has been carried on to bring the matter to the attention of the citizens of the state. It now remains for the legislature to enact the necessary laws and provide for raising the necessary funds to enable the state to carry out some comprehensive plan for the conservation and utilization of this great natural resource.

DISCUSSION.

THE PRESIDENT (CHARLES T. MAIN). — I happen to know something about some of the water powers on the Hudson River, and that within the last year or two the power developed has dropped to a very small amount. Some of them are in the hands of receivers, possibly on account of the cost of construction being greater than was estimated, and possibly on account of the fact that the flow is less than it may have been estimated, rendering necessary a greater expense in the construction and operation of supplementary steam plants.

The construction of the reservoirs described in Mr. McCulloh's paper would very much increase the value of these powers, and if the companies themselves should not have to pay for them they might increase their earnings and get out of the hands of the receivers. I was wondering if Mr. Barrows could tell us how it is proposed to have these reservoirs paid for, — whether the state is to pay for them, or whether the expense is to be distributed between the state and the owners of the various powers which would be benefited by the construction of the dams and reservoirs.

It is almost unnecessary to say that, other things being equal, the water powers which have a nearly constant flow are of more value than those with a variable flow, for if the flow is variable it must be supplemented by steam or some other power, and its value decreases as the need of supplementary power increases. The variability may be so excessive as to make the cost of maintaining and running a double plant more expensive

COST OF VARIABLE POWER AT SWITCHBOARD OF GENERATING STATION WITH HYDRO-ELECTRIC PLANT COSTING \$100 A KILOWATT AND COAL AT \$5 A TON.

Size of Plant in Kilowatts.	Cost of Hydro-Electric Power, Kilowatt Year.	Fixed Charges Steam Plant.	Total Cost when Steam Plant is run for Different Number of Months.				
			One Month.	Two Months.	Three Months.	Four Months.	Five Months.
1 000	\$12.00	\$11.00	\$25.50	\$28.00	\$30.50	\$33.00	\$35.50
2 000	11.00	11.00	24.50	27.00	29.50	32.00	34.50
3 000	10.75	11.00	24.25	26.75	29.25	31.75	34.25
4 000	10.50	11.00	24.00	26.50	29.00	31.50	34.00
5 000	10.25	11.00	23.75	26.25	28.75	31.25	33.75

than it would be to produce the same amount of power by steam alone.

If, therefore, the low flow can be increased in any way, the value of all the privileges affected will be increased.

Some time ago I presented a paper to the National Association of Cotton Manufacturers, and showed among other things the additional yearly cost of hydro-electric power due to variable power. This was summarized in a table on preceding page.

From the table it will be seen that if a hydro-electric development of 5 000 kw. costs $100 a kw. to install, the cost per kw. year on the switchboard with uniform water would be only $10.25. If it were necessary to supplement this to the full capacity for one month with coal at $5 per long ton, the yearly cost would be more than double, and for five months the yearly cost would be more than three times as much.

The effect upon the value of a property is apparent, and it will readily be seen that primary power is of very much greater value than secondary power.

The effect of the construction and regulation of storage reservoirs, if properly regulated so that they would never be exhausted and thus leave the low flow the same as it was before the reservoirs were constructed, would be to diminish the need of the supplementary steam plants. Assuming that the fixed charges on these plants are $11 per kw. year, in order to break even, one could afford to pay toward the storage reservoirs a sum which would be $11 capitalized at a proper rate for investments on this kind of property; and for every month that the steam plant is stopped on account of the steadier flow, the sum of about $2.50, which represents the approximate monthly operating cost of the supplementary steam plant, capitalized at the same rate.

If a concern had its supplementary plant and had no further use for the power, about the only saving due to the building up of the low flow would be the cost of coal saved, and the amount which such a concern could contribute toward the storage reservoirs would be on the basis of the latter sum mentioned, $2.50 per month per kw., capitalized at a proper rate.

[NOTE. — Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 1, 1911, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF PAPER, "THE EMSCHER SEWERAGE DISTRICT AND THE IMHOFF TANK."

(VOLUME XLVII, PAGE 1, JULY, 1911.)

MR. SAMUEL A. GREELEY. — It has been a great pleasure to read Mr. Saville's paper during a short visit in Essen, where the Emschergenossenschaft has its headquarters. After a visit to four plants in this district, where sewage is clarified by means of the Imhoff tank, it is evident that in this paper may be found an accurate and, at the same time, a conservative statement of the conditions governing the operation of these tanks in Germany.

There are two points which came under the writer's observation during this visit which were not emphasized in Mr. Saville's paper, and which, it seems, are worthy of brief mention.

The first relates to the treatment of storm-water sewage. Most of the districts in the Emscher drainage area are sewered on the combined plan, so that, during times of heavy rain, large volumes of sewage come to the clarification works. Until the volume of storm sewage becomes greater than about three times the average dry-weather flow, the whole sewage flow enters and passes through the Imhoff tanks. When the quantity of sewage exceeds three times the dry-weather flow, the excess is, in some instances, diverted into a special storm-water tank.

The writer saw one of these tanks in construction at the Essen north plant. This plant consists of an influent channel which leads the sewage into grit chambers and thence into an installation of eighteen Imhoff tanks. It treats the sewage of 180 000 people.

The special storm-water tank is a large circular tank with a bottom sloping to a central sump. The tank is 100 ft. in diameter, $5\frac{3}{4}$ ft. deep at the circumference and $14\frac{3}{4}$ ft. deep at the sump in the center. The sewage will enter near the center of the tank at the surface and will flow radially to a weir at the circumference. There are no partitions in this tank and it is built circular as much for simplicity of construction as for any other reason.

The particular point to be observed is that the sludge from this tank will be pumped from the sump into the influent channel leading to the grit chambers and the Imhoff tanks. Here some

pains will be taken to have the sludge mix with the inflowing sewage. The combined sludge and sewage will then pass through the grit chamber and then into the Imhoff tanks. This will afford opportunity to rot out the sludge from the storm-water sewage without going to the expense of building Imhoff tanks to handle the large volume of storm sewage.

The second point relates to the treatment of the effluent from sprinkling filters in the Imhoff tank. The writer visited a small plant at Holzwickede where this was being done with interesting results. The plant treats the sewage from about 3 500 people. It consists of two Imhoff tanks and one circular sprinkling filter with a revolving dosing arm. The sewage flows first into one Imhoff tank and is then pumped into the sprinkling filter, the effluent from which passes through the other Imhoff tank.

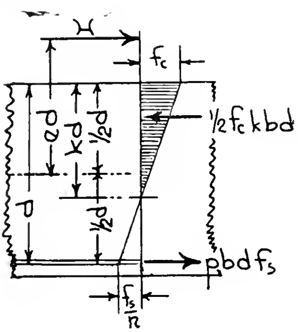
For some months after this plant went into operation, the sewage flowed in the same direction through the plant. That is, one tank always received the raw sewage and the other tank only the effluent from the sprinkling filter. It was found, however, that the sludge settling out of the effluent from the sprinkler did not decompose so rapidly or with such satisfactory results as did the sludge in the tank receiving only raw sewage. Consequently the raw sewage was turned first into one tank and then into the other. In this way each tank contained some sludge from raw sewage and some sludge from the sprinkling filter effluent. This method of operation proved more successful in accomplishing the digestion of sludge from the sprinkling filter effluent.

These two points serve to emphasize the care in both the design and operation of these tanks which is exercised in the Emscher district and which is necessary if similar satisfactory results are to be obtained elsewhere.

DISCUSSION OF PAPER, "THE DESIGN OF ECCENTRICALLY LOADED CONCRETE MEMBERS REINFORCED ON ONE FACE ONLY."

(VOLUME XLVII, PAGE 80, AUGUST, 1911.)

MR. CHARLES W. MARTIN. — Mr. Dutton has worked out a very ingenious graph for the design of concrete members, reinforced on one face only, which are to resist combined direct compression and flexure. The following analytic method for the calculation and check of such members, while it does not lead to results as directly as Mr. Dutton's diagram, may be of interest and use.



Refer to the accompanying figure and use the following notation, which is the same as that used by Mr. Dutton with the exception of such items as are preceded by an asterisk.

f_s = fiber stress in steel.
f_c = maximum stress in concrete at the compression face.
r = stress ratio, $f_s \div f_c$.
E_s = modulus of elasticity of steel.
E_c = modulus of elasticity of concrete.
n = modulus ratio, $E_s \div E_c$.
d = distance from center of steel to compression face of concrete.
b = breadth of the member.
kd = distance from the compression face of the concrete to the neutral axis.
*H = the axial stress.
*h = $H \div bd$.
*ed = distance from a point midway between the steel and the compression face to the line of the axial stress.
*M = moment, $H(ed)$.
p = ratio of area of steel to bd.
*R = resistance coefficient, $M \div bd$.

From the "straight line" theory —

$$f_s = nf_c\left(\frac{1-k}{k}\right) \qquad (1)$$

$$k = \frac{n}{n+r} \qquad (2)$$

Σ parallel forces:

$$H = hbd = \tfrac{1}{2}f_c kbd - pbdf_s \qquad (3)$$

Moments about the point midway between the steel and the compression face:

$$M = Hed = \tfrac{1}{2}f_c kbd^2(\tfrac{1}{2} - \tfrac{1}{3}k) + \tfrac{1}{2}pbd^2 f_s \qquad (4)$$

We may obtain from (3):

$$p = \tfrac{1}{2}k\frac{f_c}{f_s} - \frac{h}{f_s} \qquad (5)$$

Solving (1) and (5) simultaneously:

$$k = \sqrt{2np + \left(np - \frac{h}{f_c}\right)^2} - \left(np - \frac{h}{f_c}\right) \qquad (6)$$

Substituting (5) in (4) and simplifying:

$$R = \tfrac{1}{2}f_c k(1 - \tfrac{1}{3}k) - \tfrac{1}{2}h \qquad (7)$$

Recall that for members acting in resistance to flexure only our "straight line" values of the steel ratio, say p', and the resistance coefficient, say R', are —

$$p' = \tfrac{1}{2}k\frac{f_c}{f_s} \qquad (8)$$

$$R' = \tfrac{1}{2}f_c k(1 - \tfrac{1}{3}k) \qquad (9)$$

for members reinforced in tension only.

We may then substitute p' and R' for their respective equivalents in equations (5) and (7) and write —

$$p = p' - \frac{h}{f_s} \qquad (10)$$

$$R = R' - \tfrac{1}{2}h \qquad (11)$$

These equations indicate that for given concrete and working stresses the values of the resistance coefficient, R, and the required steel percentage, p, for members acting in resistance to combined direct compression and flexure are less than the corresponding values of R' and the required p' for members acting only in resistance to flexure by amounts directly proportional to the intensity of the direct compression.

Thus to design such members we may from tables or calculation obtain the ordinary beam values of R' and p' and by trial determine the deductions therefrom which give the correct values of R and p.

Several examples worked out by these formulæ gave results which agreed with the results obtained by using the graph under discussion.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVII. NOVEMBER, 1911. No. 5.

THE IMPROVEMENT OF NEW ORLEANS HARBOR.

BY SIDNEY F. LEWIS, MEMBER OF THE LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, June 12, 1911.]

LOCATION AND EXPANSION OF THE HARBOR.

THE harbor or port of New Orleans, as it exists to-day, occupies both banks of the Mississippi River in the parish of Orleans; in the parish of Jefferson its present and upper limit is at South Port, situated on the east bank of the river, and at Westwego, known as the Texas and Pacific Railroad Company Terminals, on the west bank of the river; and in St. Bernard Parish its present and lower limit extends as far as Port Chalmette, situated on the east bank of the river. In distance it covers some sixteen miles of water front on each bank; and, if the Mississippi River be held within its banks, — that is, the concave bends be protected from caving by erosion and encroachment of the river, — the future possibilities of expansion of this port could cover four hundred miles of river front in low river, with width and depth to accommodate the largest and deepest draught argosies of commerce that exist to-day; for the reason that in the section of the lower Mississippi River extending from Baton Rouge to the end of the levee system, a distance of two hundred and fourteen miles, the river is narrow, averaging about one-half mile in width, with depths not less than 50 ft. in the thalweg at extreme low water. Bank erosion is

very much less as compared with other sections of this river, sandbars as obstruction to navigation are almost unknown, and little if any contraction works or dredging would be required in the treatment of this stretch at extreme low water. Nature has constructed an ideal channel with depth sufficient at all times for the largest seagoing craft, and the problem is comparatively a simple but a costly one for the engineer to apply his resources to assist nature, and to maintain these banks against erosion, and thus fix the harbor lines for the destined greatest port of the world.

The extreme oscillation in stage of water is as follows:

Baton Rouge, maximum high water, 1897	40.65
Baton Rouge, minimum low water, 1894	0.45
Difference	40.20
New Orleans, maximum high water, 1903	20.30
New Orleans, minimum low water, 1872	0.42
Difference	19.88
High-water slope at Baton Rouge	0.18 ft. per mile
Low-water slope at Baton Rouge	0.03 ft. per mile

The average high-water slope from New Orleans to the Gulf is 0.14 ft. per mile, with a current of 4.2 miles per hour. The low-water slope varies with the wind and tide, with scarcely perceptible current at extreme low water.

Physical and Geographical Position of the River with Regard to the Harbor.

The accompanying chart, prepared from the survey of the Mississippi River made under the direction of the Mississippi River Commission, shows the location of the Mississippi River, and the direction of its flow with reference to the harbor of New Orleans. In the length of the present harbor the river has four bends, and four comparatively straight reaches from two to three miles in length; at two of the bends the river changes its direction something over 90 degrees, and the mean radius of curvature is about one and one-half times the river's width. The other two bends are less abrupt. The maximum depth at low water varies on different sections from 70 to 160 ft. As the city is about 110 miles inland by the river from the Gulf of Mexico, the effects of the tides are very slight and quite irregular, varying with the


A
SURVEY OF
THE MISSISSIPPI RIVER
MISSISSIPPI RIVER COMMISSION
CHART No 76
PRESENT UPPER LIMITS OF
PORT OF NEW ORLEANS
PRESENT LOWER LIMITS OF PORT OF NEW ORLEANS
PRESENT LOWER LIMITS OF PORT OF NEW ORLEANS
Stuyvesant Docks
ALGIERS

very much less as com
sandbars as obstruction
little if any contraction
in the treatment of this
has constructed an ide
times for the largest sea
tively a simple but a c
resources to assist natu
erosion, and thus fix th
port of the world.

The extreme oscilla

Baton Rouge, maximu
Baton Rouge, minimu

Difference. . . .

New Orleans, maximu
New Orleans, minimu

Difference. .

High-water slope at B

Low-water slope at Ba

The average high-
Gulf is 0.14 ft. per mil
The low-water slope var
perceptible current at e

Physical and Geogra
Rega

The accompanying
Mississippi River made
River Commission, sho
and the direction of its
Orleans. In the length
bends, and four compara
miles in length; at two o
something over 90 degr
about one and one-half
bends are less abrupt.
on different sections fr
110 miles inland by the
of the tides are very sli

stage of the river and the direction and force of the wind. The river usually reaches its maximum stage between March 1 and June 30, and its minimum stage between September 1 and November 30, and the variations in height are never abrupt. Issuing from the straight reach above Nine Mile Point, it makes a sharp bend to the right at Southport, the upper end of Carrollton Bend, with a width of about 2 200 ft. and depth of over 150 ft. at low water; these depths decrease gradually to about 70 ft., and widths increase to about 2 600 ft. at the head of Walnut Street, at the lower end of Carrollton Bend, where the thalweg crosses to the upper end of Greenville Bend near Company's Canal below Westwego with width of river about 2 250 ft., and with depths from 130 to 160 ft. to opposite lower end of Audubon Park; thence the width increases to about 2 900 ft. in the lower end of the Greenville Bend with channel depths about 80 ft. opposite Upperline Street; thence narrows to about 2 400 ft. at Napoleon Avenue, with a comparative straight reach and width of 2 000 ft. to Gretna, the upper end of Gouldsboro Bend with depth of 90 to 110 ft., and maintains this width and depth to near Algiers Point, in the lower end of Gouldsboro Bend; then the river enters the sharp bend known as the Third District Bend, below Canal Street, with a width of 1 900 ft. at the point, and depths of 160 and 170 ft. near midway of the stream, which depths are maintained to opposite Press Street, with extreme depth of 182 ft. off Mandeville Street near midway of the stream. These depths decrease and widths increase as the river straightens out below, as follows:

160 ft. depth ends opposite Montegut Street.
150 ft. depth ends opposite Clouet Street.
140 ft. depth ends opposite Louisa Street.
130 ft. depth ends opposite Desire Street.
120 ft. depth ends opposite Pauline Street.
110 ft. depth ends opposite Kentucky Street.
100 ft. depth ends opposite Ursuline Convent.
90 ft. depth ends opposite Deslondes Street.
80 ft. depth ends opposite Egania Street.

Beyond this in the straight reach it resumes its normal depth about 70 ft. to Port Chalmette, the end of the harbor; at the United States Barracks the width of the river is about 2 500 ft.

Bank Erosion in the Concave Bends — Carrollton and Third District.

The entire Mississippi River concentrated to a degree nowhere else to be found along its course, and possessing therefore its maximum power of excavation, is turned at Nine Mile Point, the upper end of New Orleans Harbor, and again at Algiers Point, about an angle over 90 degrees and with a mean radius of curvature about one and a half times the width of the river at these points. The concave banks below, meaning by that term the extreme slope from the top to the bottom of the river, which can resist such force for even a brief period, must possess great stability, or rapid excavations and deep incursions will necessarily follow, and are to be expected. From the most authentic source that can be obtained, and by comparison of bank lines from 1832 to date, the bank line in the Carrollton Bend has receded 500 to 600 ft. in the deepest recession. By comparing surveys of 1878 and 1893, in fifteen years the greatest recession, about 200 ft., was opposite Fern Street, whilst in the Third District, from 1834 up to date, the average recession between Clouet and Egania streets is less than 100 ft., and a maximum of 150 ft. between Lesseps Street and the upper end of the property of the Ursuline Convent. There can be but one explanation of these differences, that the bank in the Third District possesses a stability which is truly remarkable, and that this stability has been fortified by artificial means. The upper portion of this bend has been occupied by the city of New Orleans from the time of its foundation, and the lower part has been taken up by commerce as the city grew, and has been occupied for many years with skeleton wharves, which from time to time have caved into the river, but been rebuilt on pretty much the same alignment. If the channel of the Mississippi within the limits of the port of New Orleans could be emptied of its water, so as to expose it to the bottom, dry and bare, the appearance would be surprising to the ordinary layman. Instead of a comparatively level bed corresponding in a general way to the surface of the river, and its adjacent banks, there would be found a succession of great sand hills, and intervening crescent-shaped depressions, of one hundred feet or more, or, as Mark Twain would have it, resembling the serrated edge of a buzz-saw.

Bank Protection Work by the United States Government.

Everything has its beginning. So did bank protection or early subaqueous revetment work in the harbor of New Orleans

as it existed in 1877 and 1878, for which the incentive was purely the protection of property. Previously to this time, in the Missouri River, the silt-bearing tributary of the Mississippi, for resisting the impact of the current and preventing the erosion of the banks, a variety of devices had been tried with more or less success. Among the most satisfactory of these may be mentioned the woven brush revetment, the continuous mat, or brush blanket, made of brush sewed together with wire, and the willow screen. This character of work as applied to the Mississippi River in front of New Orleans harbor, originated from a survey made in the winter of 1877 and 1878 through a report of a Board of Engineers composed of the following: G. Weitzel, major of Corps of Engineers, U. S. A.; W. H. H. Benyaurd, major of Corps of Engineers, U. S. A.; C. W. Howell, major of Corps of Engineers, U. S. A.; Major B. M. Harrod, chief state engineer; J. A. D'Hemecourt, city engineer, who were convened at the request of the city authorities of New Orleans, to consider plans for the protection of the harbor of New Orleans from the effects of caving banks of the Mississippi River along the river front. The report submitted by this Board of Engineers briefly recommended that in the treatment of the river in the Carrollton and Greenville bends, where no wharves existed, the slopes of the river bank should be covered from a short distance above low-water mark to a distance out such that all defective strata would be protected, by a layer of brush formed into rafts and ballasted with stone sufficient to keep them in position. In the Third District it was deemed advisable to apply protective measures to the slope of the bank from Morgan's Wharf to Congress Street, a distance of 7 500 ft., by a pile bulkhead to be driven extending the entire distance in a line with the outer row of existing wharf piles; the piles to be of pine 12 in. at butt and 65 ft. in length, driven in pairs 6 ft. between centers, longitudinally, and driven until their tops were on a level with the decking of the existing wharves; between the piles of each pair a clear space of 3 ft.; the piles to be bolted together at low water, and at the top; between the piles extending up and down stream brush fascines to be placed to low-water mark, forming, so to speak, a brush wall, above low-water mark; land side of this wall the bank to be revetted with wooden sheet piling to high-water mark. From the foot of this row of piles, extending out as far as may be necessary, about 200 ft., to cover all defective strata, a layer of brush and stone was to be laid upon the slope. As the largest interests involved were in the Third District, it was

deemed expedient that the proposed measures of protection should be first applied to that part of the harbor. The total estimated cost of the project was figured out at \$476 000. On this report an appropriation of \$50 000 was obtained by act of Congress, approved June, 1878, and subsequent appropriations were made by the United States government as the work progressed, aggregating some \$260 000. The carrying out of the plan and methods to be pursued in the conduct of the work were in charge of Major C. W. Howell, Corps of Engineers, United States Army, and applied from 1878 to 1881. Operations were carried on during the low-water seasons of 1878, 1879, 1880 and 1881, the work for the first three years being confined to the Third District, while the greater portion of the work done in 1881 was in Carrollton Bend. The following was the method of construction: A mat or carpet was first made in small sections 24 ft. by 25 ft., the material used being fish-pole cane instead of brush on account of its abundance in this country. In the finished section the canes lay in a single layer, side by side, with sufficient interval between them to allow for the stitching, about one inch. It was sewed from one end to the other by seven continuous pairs of wires or pieces of marline, the latter being used to the exclusion of wire after a few mats were placed. The stitch was the shoemaker's stitch; that is, one marline passing under one cane, passed over the next, under the third, over the fourth, and so on, while the other marline of the same pair alternated in the same manner, but passed on the opposite sides of the canes. The two pieces of marline thus crossed each other at each interval between the canes; in crossing they were not caught together. They were secured only to the middle and end canes of the section. The breaking of a marline at one point destroyed its efficiency throughout its length. An opening was made in each joint of each cane to destroy its buoyancy, and admit sediment from the river after sinking. These sections were then carried on board the floating ways, and eight of them were sewed together, end to end, making a mat 200 ft. by 24 ft., and it was in this shape that the mats were put down during the seasons of 1878 and 1879. For placing them a row of guide piles 6 ft. apart was driven upon the line of the front wharf piles, which piles were intended to subsequently form part of the brush wall described in the plan. An iron ring was slipped over each pile, fitted loosely, to which the end of the mat, the 24 ft. side, was secured by a piece of light rope. The barge upon which the mat was spread was then moved out into the stream

by a tug-boat, the mat was launched and placed upon the bottom with its longer side as nearly as possible perpendicular to the shore. The ballast used with the first few mats was old boiler-tubes filled with sand, and afterwards canvas bags filled with sand. No other ballast would answer the purpose because it had to be permanently fastened to the carpet; buoys were attached to each mat before sinking, by means of which its location upon the bottom could afterwards by approximately ascertained. There was much irregularity in the sinking. The presence of ships at the wharves was a serious inconvenience to the work, causing frequent interruptions. It could not be made continuous.

The work done in 1878 and 1879 was begun just below Picayune Pier, and extended to the foot of Mandeville Street, covering a length of 1 116 ft. measured along the bank. It consisted entirely of matting of the above description, nothing being done towards the brush wall except the piling. In 1880, it was found impossible to begin at Mandeville Street where the work of 1879 terminated, because the wharf master refused to move the ships that were moored between Mandeville and Montegut streets. Work was accordingly begun at Montegut Street, leaving a gap of 2 262 ft. between that and the work of 1879. The general construction of the mats was the same as before, except that they were made larger. Forty sections, each 14 ft. by 25 ft., were sewn together, making a mat 200 ft. by 70 ft., instead of 200 ft. by 24 ft., as before. Floating ways, having the direction of their slopes parallel to the shore instead of perpendicular to it, as before, were moored to the guide piles. The mat, being secured to the latter in the same manner as before, was launched up and down stream instead of across stream, as before. Ten such mats, covering a length of 560 ft. of bank between Montegut and Louisa streets, were laid in 1880. The ballast used was sand bags. Two mats similar to those of 1880 were laid in 1881, when the floating ways were blocked from further progress downstream by the presence of a large ship engaged in loading at the only wharf remaining available in the Third District. The wharves in front of which the work of 1878 and 1879 was done fell into the river in the spring and summer of 1880. They were rebuilt, and wrecked again in 1881. These mats were of little permanent value, the cane proving not a good material owing to its straightness, smoothness and rigidity, depriving it to a large degree of the silt-catching quality which is of so great importance in the revetment of the banks of the river. The work had been done in a desultory way in the Third District, and the upper end of

Carrollton Bend, and by order of the Secretary of War, September 28, 1881, in accordance with the recommendation of a Board of Engineer Officers, composed of Majors Charles R. Suter, W. H. H. Benyaurd and Amos Stickney, and Capt. O. H. Ernst, who were convened by the Chief of Engineers to consider and report upon the work of improvement of the New Orleans Harbor, the plan was discontinued after some 96 031.75 sq. yd. of the sloping portion of the river bed had been covered, 47 575.64 sq. yd. in the Third District, about 1 700 linear ft., and 48 456.11 sq. yd. in the bend at Carrollton, about 2 268 linear ft., at a cost of $114-546.72, or about $28 per linear ft. out of a total amount appropriated of $260 000. A re-survey of the bend at Carrollton and the one in the Third District was at once commenced, in accordance with the instructions of the Board of United States Engineer Officers, and upon its completion the Board reassembled at New Orleans, February 17, 1882; upon a comparison of the sections and profiles of the surveys of 1878 and 1881, the Board reported to the Chief Engineer, on February 20, 1882, that the banks of the river in the vicinity of New Orleans are stable: that in the concave bends there is a slow and gradual erosion at places, where the stability of the bank has not been reinforced by the remains of old wharves and bulkheads; that the frequent wrecking of the wharves is due not to the erosion of the bank but to the sloughing of the silt deposited among the wharves at high water, where these are located upon a steep slope. There are presented in the river front of New Orleans two distinct problems, viz.:

First, the protection of the wharves, and

Second, the protection of the bank from erosion.

The first problem appears principally in the Third District; at this locality the stability of the bank is so great that no further protection seems necessary below low-water line. Above that line the slope as far up as the line of bulkheads is now protected by the presence of the wharves, and still farther up is partially protected by the bulkheads themselves. For the protection of the wharves there seem to be three alternatives, viz.:

First, to so construct them that they shall not cause heavy silt deposits; or

Second, to make them strong enough to withstand the strains brought to bear upon them by the sloughing; or

Third, to gradually remove the deposits by artificial means before they have an opportunity to slip in mass.

The first remedy may be accomplished by providing floating

instead of fixed supports. The second would require a form of construction much more substantial than any heretofore used at this locality, and would be experimental. The third is easily accomplished, if it be kept in view when the wharves are constructed. A powerful tug presents probably the easiest and quickest means of removing large masses of silt. The disturbance caused by the motion of her wheel will effect an excavation at a considerable distance, and will be effective at the greatest distance which will be necessary in this case; openings between the wharf-heads should be left for the admission of such a tug, and as soon as the deposits have acquired any considerable volume, and before the river has begun to fall from its high stage, she should be set at work within the wharves and between the piers leading to them. By this means the pressure of the silt may be prevented from becoming excessive. As an additional precaution, greater care should be exercised in placing the piles which support the wharves. Fewer piles should be used, and these should be heavier than those now used, and should be driven to much greater depth. The wharves, in many cases, seem to have been constructed with the conviction that it was impossible to make them durable, and the cost of their construction has been kept as low as possible. Piles have been driven, as a rule, to a depth of about 12 or 15 ft., and never, so far as the Board can learn, to a depth greater than 25 ft. This depth should be increased to about 40 ft., etc.

In Carrollton Bend the problem of bank protection alone is presented. A comparison of the sections shows that no great changes have occurred here since 1878, but as considerable erosion took place in twenty years preceding 1878 and as there is no reinforcement by artificial means of the natural stability of the bank, it seems desirable that a revetment should be constructed. To be efficient, the protection of the slope below the water line should extend to the bottom of the river; this will require a mattress about 400 ft. wide. It is essential that every portion of this surface should be covered; and, to insure this, the mattress when in place should be continuous, either by an absolutely continuous construction, making one single mattress for the entire length of the bend, or by the thorough overlapping of contiguous sections, which should be made of the greatest practicable length. The mattress should be so adjusted as to possess the greatest silt-catching power, etc. The approximate estimate for the cost of such construction is figured at $28 per running foot of bank. The total length of bank in Carrollton Bend

is about 10 000 ft.; at $28 per foot, the estimated cost will be $280 000. The River and Harbor Act of August 2, 1882, relegated this work in the general plan for improving the Mississippi River to the Mississippi River Commission, for the Mississippi River Commission was created by act of Congress, approved June 28, 1879. The law provided that it should consist of seven members, of whom three were to be from the Engineer Corps of the Army, one from the Coast and Geodetic Survey, and three from civil life, of whom two were to be civil engineers by profession. Its duties were defined in part as follows: "To take into consideration and mature such plan or plans and estimates as will correct, permanently locate and deepen the channel, and protect the banks of the Mississippi River; improve and give safety and ease to the navigation thereof; prevent destructive floods; promote and facilitate commerce, trade and the postal service."

Improvement of the New Orleans Harbor by the United States Government.

The work of improving the harbor of New Orleans under direction of the Mississippi River Commission may be said to have been commenced in the winter of 1883–4, when a mattress of the continuous woven type, 400 ft. wide and 470 ft. long, was sunk at the head of Carrollton Bend in December, 1883. The mattress-ways were 28 ft. wide and 400 ft. long; they were constructed across the ends of ten barges, each of which measured 100 ft. by 20 ft. These barges were separated by a space of $22\frac{1}{2}$ ft. and were so linked together that high waves could not injure them or the mattress-ways. The plant was placed in position at the head of Carrollton Bend. The willow brush was woven on poles, with iron rods fastened to them. The poles and rods were 25 ft. long, and when one set had been woven full of brush another set was linked on. Two No. 8 wires ran through and across the mattress every 12 ft. of its length, and heavy binding poles were wired across every 25 ft. of length. Some 470 ft. of continuous mattress was sunk, when, owing to serious and rapid caving of river bank in Gouldsboro Bend on the right or west bank of the river, involving much loss to property of considerably greater prospective value than in Carrollton Bend, the attention of the United States government, the following year (1884), was directed to the protection of this bend of the New Orleans Harbor, and the plan adopted was to use spur

dikes 300 ft. long instead of the continuous mattress, built out at right angles to the bank; the spurs were located at such distances apart, from 500 to 1 600 ft., that the current deflected from one will reach the next before it strikes the bank. The spur dike consists of a foundation mattress of willows, brush and timber, of same design with improved modification as the original woven mattress used in Carrollton Bend, 150 ft. wide by 350 ft. long, which is first sunk in position, and which was intended to prevent any scouring action on the river bottom by eddies or local currents which may be produced by the dike. On this mattress the dike is built up by sinking successive layers of mattresses or cribs of diminishing widths, the construction of which is similar to that of the foot mattress, except that they are made thicker. The work is so planned that the top of the completed dike at the shore end will be below low-water line, and the crest of the dike has an approximately regular slope of about three horizontal to one vertical, its outer end resting on the river bottom in deep water.

Spur No. 1, laid in the upper end of Greenville Bend in 1889–90, is worthy of special mention as being the largest structure of its kind ever placed in the Mississippi River or elsewhere. It contained in round numbers 3 400 cords of willow brush, 80 000 ft. of lumber, 2 000 tons of rock, 5 500 lb. of wire, 60 kegs of nails and spikes, and 8 000 lb. of iron rods and chains. Its length was 430 ft., its maximum height 60 ft., and the depth of the water at its outer end was 152 ft. at low water. In addition to these dikes, continuous bank revetment in later years has been constructed in the intervals, where the destructive forces have proved very active. This revetment has an average width of about 400 ft., and extends from low-water line out to deep water, covering the entire bank slope. In building this revetment mattresses are made of willow brush and poles, and fastened with sawed timber and wire, and are first constructed in sections of convenient size, about 2 ft. thick. These sections are then fastened together, forming a large mattress, which has a width of 130 to 150 ft. and a length equal to the width of the revetment, 300 to 400 ft. This mattress is floated to position between lines of barges secured by mooring lines, and is sunk by loading it with rock evenly distributed over its surface. After it is sunk additional rock is deposited upon it.

The effect which the continuous revetment is intended to produce is to cover the entire bank slope directly after the caving for the season has ceased, and when the bank has presumably a

form best adapted to stability, and to protect it from further erosion. The dikes are designed to arrest caving by checking the velocity of the current, and inducing a deposit, and to support the bank. Spur dikes without immediate revetment have been successful in some of the straight reaches, and on concave banks of large radius, but in the abrupt bends the dikes alone are only locally effective. It was estimated in 1897 that the cost of bank protected by the United States government was $37.70 per running foot.

Bank Protection Work by the Orleans Levee Board in the Third District.

On August 20, 1897, Mr. L. W. Brown, a civil engineer of note and ability, who had been elected at a previous meeting assistant engineer of the Orleans Levee Board, made an elaborate report on the condition of the levee and bank lines in the Third District, from Clouet Street to Jackson Saw Mill, and recommended to the Orleans Levee Board the construction of a continuous skeleton pile wharf of the usual type of construction as a bank protection measure. His plea for such construction is expressed as follows:

"Any measures having for their object the preservation of a caving bank, or a bank which the current is impinging with abrading force, from further caving, that do not provide a uniform impingement throughout the stretch, where the caving bank exists, for the current to strike against, and thus remove the irregularities in the current, such as counter currents, cross currents, eddies and whirlpools, cannot be a permanent success. On the other hand, if measures on these lines are adopted whereby the current can be guided past the abrading bank at a uniform velocity, the structure required to accomplish this end would necessarily have to be of such character as to impede the velocity and allow deposits to form, and gradually any desired extension could be made riverward throughout the stretch of caving bank; as such a structure would provide a resistance more than equal to that which is required to force the current towards the opposite shore or point, and would abrade same, and the channel of flow would be thus forced over towards its original position," etc.

And again,

——"from personal observation during the past high-water season, have demonstrated thoroughly, to my mind, that if the surface flow of the river, which under certain conditions has greater velocity, can be checked, where it sets against the bank, it very materially interferes with the force of the lower currents,

and reduces its power to scour, and I am now thoroughly convinced that unless you can check the surface currents, no real benefits can be expected from submerged structures," etc.

The same character of work was subsequently recommended by Mr. Brown for the Second Street cave, the Third District Reach from Jackson Saw Mill to the Barracks, and the Carrollton Bend. The Orleans Levee Board undertook and did carry out this plan of bank protection in the Third District, without the approval of the Board of State Engineers, at an expense of nearly two hundred thousand dollars. On August 23, 1898, one year after the project was adopted, a cave and subsidence of the bank took place in the Third District, from a point about one hundred feet below the head of France Street, and extending upstream for a distance of 810 ft., and the fore shore and skeleton wharf for a length of 1 115 ft. were carried in; notwithstanding this object lesson the work of repairing same and reconstruction of other parts continued. To-day there is not a vestige left of this pile bank protection work; it has either caved into the river or rotted out, and the areas occupied by the decayed piles and débris of the skeleton wharf had to be cleaned and cleared at a cost of $26 591.60 by the Orleans Levee Board in 1908, so that the United States government could lay the submerged continuous mattresses to protect these banks.

Amount of Work Done up to Date by the United States Government.

Up to date, the following amount of bank protection work in the harbor of New Orleans has been done by the United States government under the direction of the Mississippi River Commission. "The revetment in the Carrollton Bend now has a length of 13 330 lin. ft., and consists of 3 975 ft. of continuous mattress 400 ft. wide, 3 955 ft. of continuous mattress 300 ft. wide, 3 365 ft. of continuous mattress 250 ft. wide, placed generally with its inshore edge along the 60 ft. contour, and 2 035 ft. protected with five submerged sloping spur dikes in conjunction with continuous mattress. In the Greenville Bend, there is now 1 570 lin. ft. of continuous mattress 300 ft. wide. On the Gretna Front, 2 795 lin. ft. of continuous mattress 300 ft. wide. In the Gouldsboro Bend, 9 475 lin. ft. protected by 24 submerged sloping spur dikes. In the Third District Reach, 9 400 lin. ft. of continuous mattress from 300 to 400 ft. wide in conjunction with sixteen submerged sloping spur dikes, and 1 110

lin. ft. of continuous mattress from 200 to 300 ft. wide. The total length of bank protected wholly or in part is 37 680 lin. ft., about $7\frac{1}{8}$ miles. The 1 940 ft. nominally protected by two spur dikes placed in the Greenville Bend in 1889–90 is omitted from the total, since these dikes, although apparently intact, have been flanked and the caving is continuing back of them. Two of the mattresses sunk in the Carrollton Bend, to prolong the work of previous years from the 60 ft. contour up to low-water line, have slipped down the hard clay bank, which has an inclination of one in two; a survey indicated that no caving of the bank had occurred in the vicinity; with the exception noted, all of the work so far is known to be in good condition. Net field cost of season's work, $122 933."

The urgency of the work required to be done in the New Orleans Harbor by the United States government has long been admitted, and time and time again has the government been appealed to by her commercial bodies, *et al.;* the Board of Levee Commissioners of the Orleans Levee District have repeatedly announced that if the national government will undertake the task of bank protection, the district will construct and maintain all the levee lines required. In order to do this, it will be necessary for the government to mattress all bends from Southport down to the end of the harbor, without reference to parish lines; the arrest of encroachment in the bends will reduce to a certain extent accretion on the opposite bank, but to do this work effectually would require an annual expenditure of $300 000 and that is what all interests in the harbor of New Orleans should combine to obtain from the United States government until the work is completed.

The total amount received from the government for this work since its incipiency, 1878, up to date, as shown in the following table, is $1 824 391.34. This shows the average amount of work done per year for thirty-three years to have been about $55 000.

New Orleans Harbor.

ABSTRACT OF APPROPRIATIONS.

"Improving Harbor at New Orleans, La."

	Allotted.	Amount.
June 18, 1878 (river and harbor)........		$50 000.00
March 3, 1879 (sundry civil)........		60 000.00
June 16, 1880 (sundry civil)..........		75 000.00
March 3, 1881 (river and harbor).......		75 000.00
August 2, 1882 (river and harbor).....	By transfer.	162.86
January 19, 1884 (river and harbor).....	By transfer.	1 400.00
July 5, 1884 (river and harbor)........	By transfer.	4 900.00
July 13, 1892 (river and harbor).......	By transfer.	80 000.00
August 18, 1894 (sundry civil)......		110 000.00
June 3, 1896 (river and harbor).........	June 27, 1896.	110 000.00
March 3, 1899 (sundry civil)...........	March 13, 1899.	110 000.00
Received from sale of property		38.63
		$676 501.49

"Improving Mississippi River, New Orleans Harbor."

	Allotted.	Amount.
August 5, 1886 (river and harbor).......		$75 000.00
August 11, 1888 (river and harbor)......		199 888.00*
September 19, 1890 (river and harbor)...	Oct. 15, 1890.	90 000.00
September 19, 1890 (river and harbor)...	Dec. 14, 1890.	10 000.00
September 19, 1890 (river and harbor)...	By transfer.	8 000.00
June 4, 1897 (river and harbor)........	By transfer.	10 000.00
June 4, 1897 (river and harbor)........	By transfer.	40 000.00
June 13, 1902 (river and harbor)........	July 12, 1902.	95 000.00
March 3, 1905 (sundry civil)...........	April 26, 1905.	85 000.00
June 30, 1906 (sundry civil)............	June 28, 1906.	10 000.00
March 2, 1907 (river and harbor).......	July 12, 1907.	100 000.00
May 27, 1908 (sundry civil)............	May 4, 1908.	150 000.00
Received from sales blueprints..........		1.75
March 4, 1909 (sundry civil)...........	April 28, 1909.	100 000.00
June 25, 1910 (river and harbor)........	July 25, 1910.	175 000.00
		$1 147 889.75
Grand total..................................		$1 824 391.24

* Original appropriation, $200 000; $112 reserved by the Chief of Engineers for office expenses.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 1, 1912, for publication in a subsequent number of the Journal.]

THE PANAMA CANAL.

By John F. Stevens, Member of the Oregon Society of Engineers.

[Read before the Society, March 9, 1911.]

When I accepted an invitation to address the members of this Society this evening, the subject selected was the Panama Canal, and I was to choose such particular phases of that subject as I might elect to talk upon. But several of my friends to-day have told me it was generally understood I had something sensational to declare, presumably as to the attitude of the railroads to canals. Now, I am not authorized in the least to speak for the railroads, or for any one of them, on this matter. But I have my individual opinion, and in order that there may be no misunderstanding as to that opinion, I beg to say: Some two and one-half years ago I had the honor to speak before the first annual convention of the Atlantic Deeper Waterways Association at Baltimore. The subject assigned to me was "The Relation of Railways to Canals," and I am going to read you extracts from my remarks at that time, which will, I think, clearly indicate my position. I may say my views are the same to-day, only stronger, and that they apply to all canals, properly located and constructed, including the one under consideration.

"But the gigantic strides our internal commerce has made have demonstrated that while railways serve a purpose which waterways can never do, they need to be supplemented by a cheaper, if slower, carrier. There are immense volumes of low-grade traffic which, to be moved at all, require very low rates. Such traffic is now being handled by the railways, to the detriment of their other and faster-moving business, resulting in a loss to themselves and to the public also.

"There seems to be a general impression that the railways are opposed to the exploitation and construction of canals. That there is good ground for such opinion the speaker does not believe. The concensus of opinion among our ablest, most far sighted railway owners and executives is undoubtedly that canals, properly planned, honestly financed and constructed will not only aid the development of the country, but will create new business and, from other and potent causes, be of assistance and value to the railways themselves. Beyond a doubt, they will take from the railways some part of a certain class of traffic, but such loss will be recouped by the fact that the railways will

be enabled to better and more economically handle the higher-priced traffic, which the waterways can never satisfactorily do, and so the net results will be for their benefit.

"It is lamentably true that the roads have not been able in recent past times, owing to the increase of business going ahead of their facilities, to handle promptly the traffic thrust upon them. That this traffic has increased in far greater volume than have additions and improvements been made to the carriers is a fact which needs no elaboration. And, for reasons which need not be entered into here, but which are very apparent to all thinking men, just at a most critical time, the power to extend and improve present facilities was taken from the railways; so that when business resumes — as it surely will — its late lamented and probably much increased activity, it will find itself hampered and throttled to an extent it has never known.

"The inevitable loss will be borne by all alike, from the strongest, most powerful corporate interest to the humblest individual citizen — none will escape. Already this baneful effect has been felt; but what has happened in the past will be but a summer cloud to a torrential storm, to what may come. In our industrial world — which means all our world — there will be no distinction between the agricultural, the manufacturing, the transportation, the mining, the mercantile, the professional or the laboring people. The enlargement of our carrying capacity must keep abreast of the expansion of our commercial interests. Already the former is lagging, and no greater question (and one which is already more than insistent — it is absolutely clamorous) is presented than the one of how to provide the ample transportation facilities our business will require.

"So it will be that the railroads, by collaboration with waterways, natural and artificial, and by establishing coördinate relations with them, will solve the great transportation problem which presents itself, and which must be settled, and settled right, unless the hand of commercial progress is not only stopped but set back.

"It will be generally conceded that, from a commercial standpoint, we are a nation, and not merely a collection of scattered cities, districts or states, each with its own interests separate and independent of the rest, so that if from any cause business is affected favorably or otherwise at any point in our country, such effects never fail to be reflected at every other point; naturally, all are benefited or harmed, as the case may be. It then follows, as all business depends upon transportation for its very life, that the great problem of ways and means for conducting it is not confined to narrow limits, but involves the entire country."

I want to call your especial attention to my reference to our nation as a whole, because what I may say about the commercial aspects of the Panama Canal applies to the United States as a whole and not to Oregon, nor to the Northwest, alone.

And if you notice points that apparently do not harmonize geographically, remember that I have a good precedent in following the lead of a very eminent man, whose tariff speeches in the last campaign were evidently intended not to be used in the East and West indiscriminately. As I hope the above statements dispose of any expected sensation, I will say further:

Nearly four years ago I addressed the members of the University Club of a prominent New England city on the same subject that we have before us to-night, "The Panama Canal." Although no report was supposed to have been made of the meeting, I soon found that distorted quotations and false versions of what I had said were creeping into the press, and in deference to the advice of some of my misguided friends, I had a few hundred copies of my very sketchy notes printed for private distribution. As the very limited time I have had to prepare for this evening precluded any attempt to formulate a set address, I have concluded that I can do no better than to read to you, with your kind indulgence, somewhat from a printed copy of my former effort, supplemented by whatever additions of a verbal nature may occur to me to be appropriate, considering the lapse of time that has occurred.

The conception of the possibility of uniting, by artificial means, the waters of the Atlantic and Pacific oceans was a resultant of the many and often visionary projects entertained by the bold, and generally unscrupulous, spirits who not only ruled Spain when she was at the zenith of her power, but carried her flag and prestige to all parts of the New World, as it was then known. With few exceptions, every agitation, great or small, of any part of the human race which has culminated in a movement to seize, explore and hold distant regions by force of arms has been dictated by avarice. The fabulous reports brought to Spain by Columbus, and by the early adventurers who followed him, of the wealth in gold, silver and precious stones in the new countries, raised up a horde of legalized bandits, whose exploits history has, with more or less accuracy, set forth.

Columbus, as we know, died without knowledge of what lands he had touched, believing them to be a part of what was then popularly called Cathay, or what is now known as the East Indies. Balboa, by his trip into the unknown wilderness, first demonstrated that beyond the lands so far only really seen from a ship's deck, there existed another body of water, which was finally proven to dwarf the Atlantic in size, and which was separated from it by only a comparatively narrow strip of land.

Balboa early fell a victim to the jealousy of his fellow-adventurers and was not permitted to live to extend his discoveries, but he was followed by others as enterprising and unscrupulous.

The timbers of the first ship which plowed the waters of the Pacific Ocean, manned by white men, as far as history, or tradition, if you please, tells us, were laid in a small bay on the southern side of the isthmus of Darien by one of these adventurers, and these timbers were cut on the shores of the Atlantic, hewn into shape and carried across the isthmus to the shore of the Pacific, and were there put together for the first voyage into the unknown sea. This work was performed by natives seized and held as slaves by the Spaniards, who without such enforced labor could have done little, but who with the cross in one hand and the sword and torch in the other forced the civilization of medieval Europe on to the greater part of the new world.

The conquest of Peru, the spoliation of her wealth by Pizarro and the men who followed him, are matters of history. The most natural route by which all the spoils of conquest which were claimed by the crown of Spain could be sent home, was by the west coast of South America, thence across the isthmus and over the Atlantic to Spain. This practice, with the necessity for a port on the south side of the isthmus, brought into existence the city of Panama, and from Panama northward across the isthmus the Spaniards constructed a road, paved with stone, wide enough for two heavily laden mules to pass, and over which for years crossed and recrossed the pack trains which kept open the lines of communication between the Pacific Ocean and the plate ships of Spain. This old road still exists, and I have traveled over miles of it still in fairly good condition, and giving ample evidence of the thoroughness with which such works were then carried out.

All of these millions of treasure did not reach Spain; Panama in those early days was accounted the richest city on earth in proportion to the number of its inhabitants, and we can be well assured that it took full toll of all treasure passing its portals. Then, too, the English lay in wait by trail and on sea, and Drake, Hawkins, Morgan and the rest played the part of the eagle to the fishhawk, robbing the latter early and often of his prey. Buccaneer Morgan finally captured the original city of Panama, burned it, butchered many of its people and scattered the rest into the jungles, from which years afterwards they reassembled and built the city of Panama which now exists,

and which is near the south end of the canal now under construction.

History alleges that the idea of cutting a shipway across the isthmus, to avoid the long and dangerous passage around the Horn, took shape in those early days, even going to the extent of carrying out of extensive explorations to select a feasible route. Be that as it may, nothing tangible resulted for more than three hundred years. Possibly this delay can in part be explained by an edict which it is said that Philip the Second promulgated, that of prohibiting any Spanish subject from even mentioning such a project on penalty of death, and which edict, it is said, has never been revoked; and there are yet people who point to this law as a proof of the great wisdom of Philip — a claim which each student of history can settle for himself.

Lord Nelson suggested a canal at Nicaragua in 1780, and early in the last century Baron Humboldt is said to have mapped several routes, one of which was over the line practically now adopted. Spain also woke up again, along in 1820, and talked canal; but as she lost control of the isthmus about that time, she did nothing. Along about 1840 several of the Central American states tried to interest Louis Philippe in the project, but without success. The rush of travel and business resulting from the discovery of gold in California in 1849 so stimulated interest that as a consequence the Panama Railroad was built and opened in 1855. From this time on different schemes were proposed, and in 1879 the French becoming interested, surveys were carried on by Lieutenant Wyse, a Frenchman who a year before had secured a concession from Colombia to build a ship canal.

Ferdinand DeLesseps, with the prestige of, and fresh from the completion of, the Suez Canal, took up the matter, and a congress convened by him in Paris decided in favor of a canal from Limon Bay (Colon), on the Atlantic side, to Panama Bay on the Pacific side. This congress also decided a sea-level canal should be the type to be built.

Previously to this time, in 1852, the United States had undertaken and carried out at spasmodic intervals surveys for a canal at Nicaragua, and in 1889 an American company was formed for the purpose of constructing a canal along the lines developed at the latter place, but nothing of practical importance was accomplished beyond the completion of surveys.

Attention had also been called to what is known as the

Darien Route, some one hundred miles eastward from the Panama Route, and it has been thoroughly reconnoitered, though no close instrumental surveys have been made. Some features of this route are favorable: There are fairly good harbors at each end, and it is the shortest route across the isthmus of the three which time and study have selected as the only ones worthy of consideration; but its adoption necessitates the construction and maintenance of a tunnel nearly five miles long — a proposition which, owing to its size and importance and the difficulty of securing an absolutely safe and sound roof, it is believed our best engineers would hesitate to endorse.

Right here I give as my individual opinion that, granting an inter-ocean canal was to be built, physically, financially, and for all other reasons, and after all arguments are balanced, the decision choosing the Panama Route, so-called, was the correct one.

In 1881, after organization and preliminaries had been attended to, active operations by the DeLesseps Company — it having secured the Colombian concession from Lieutenant Wyse — were begun. The Canal Company purchased the Panama Railroad from the company which up to that time (1882) had owned and operated it. Besides, from its location, lying as it does not only along, but in a number of places upon, lands actually needed for the construction of the canal, and from its importance as an adjunct, as furnishing the necessary means of transporting not only supplies but waste material from the canal prism, its control by the canal builders became — and is yet — an absolute necessity.

The history of the DeLesseps' attempt to build the Panama Canal is set forth at such length and in such details in various publications that a lengthy résumé of it here is unnecessary.

As noted previously, the original decision was for a sea-level waterway; but as time went on, as vast sums of money were raised and spent without commensurate progress, it was decided to abandon the sea-level idea and substitute locks, and to the trained eye of an engineer the history of those years, as money became harder and harder to raise, is plainly written on the face of the work. First, a two-lock plan was attempted, then more and more locks were added, until the holes in the ground for these locks which I found apparently increased in number as the bank account grew less — a pathetic story, needing no words to understand.

In 1888, the company broke with a crash that attracted

world-wide attention, and which before its echoes died away dragged many a name, before honored, into the dust, and undoubtedly hastened DeLesseps' death. At the time of cessation of the work, it is likely that more than $250 000 000 had been spent, and conservatively not over one sixth of the actual work had been accomplished. And more vital, a satisfactory plan to care for the most important, in fact, the one prominent engineering feature of the whole enterprise, the control of the Chagres River and its tributaries, had not been solved or adopted.

In 1891, the company having been reorganized, an extension of the concession was granted by the Colombian government, and work was again begun, and continued in a very small way — just enough to hold the concession — until the United States took over from the new French company all its property, plant and interest in the project, by the payment to it of $40 000 000, which arrangement, all things considered, was a fair, without being a great, bargain for the United States.

As certain rights and privileges not held by the French company, and consequently not transferred to the United States, were considered necessary, negotiations looking to the making of an arrangement with Colombia were begun, and after long delays a fairly satisfactory treaty was formulated, which, however, was rejected by Colombia in 1903 — quite unexpectedly, it is said, to the officials of the United States. But, by a curious coincidence, shortly after the rejection by Colombia of the proposed treaty, the province of Panama, an integral part of Colombia, seceded from its allegiance to, and by one of those comic opera revolutions separated from, Colombia, and set up an independent republic of its own. How this was accomplished is perhaps a matter of correct public history — perhaps not. There are critical people yet who, in the blindness of partisan spirit, still decry the alleged actions of the United States at the time of this revolution, but an honest judgment would indicate that this matter should be considered as a closed incident. Regardless of any ethical question involved, there would seem to be times in political history when the principle of the end justifying the means would apply. Be that as it may, the practical result was that the United States was enabled to effect a satisfactory treaty with the new republic of Panama, failing in which it would probably have been forced to revert to Nicaragua, if it desired to build a canal, as it had fully determined to do. Among other details of the arrangement with Panama was the payment, under certain terms, of $10 000 000 by the United States to the new

republic; thus the United States obtained a clear field from all parties interested by the payment of $50 000 000.

Under this treaty the United States gained the sovereignty over a strip of land ten miles in width, five miles on each side of the center line of the canal, extending from the usual three-mile limit in the Caribbean Sea to the same limit in the Pacific Ocean at Panama. This right, however, is not clearly understood by the average man: It is not a fee simple, but it is probably broad enough to answer all purposes.

It grants to the United States power to locate, construct, maintain and forever operate a ship canal connecting the two oceans, with ample power to establish governmental, including police and sanitary, regulations. Excluded from the ten-mile strip are the two cities of Colon and Panama. The power of the United States to regulate sanitary matters, however, extends over these two cities. The United States also has authority, in case it becomes in its opinion necessary to preserve order, to enter these cities with armed forces and take possession of them. The United States also practically guarantees the republic of Panama all needed assistance, armed or otherwise, to enable it to preserve its independence.

Since the occupancy of the Canal Zone by the United States, it has maintained large bodies of police and marines, both in a highly efficient condition, and until the year 1907 kept a war vessel in commission in the harbor of Panama. There is little likelihood of serious trouble, unless as between the two political parties into which the people of Panama are about equally divided. If, however, the government of Panama should in its blindness attempt to seriously antagonize our interests, probably another cardboard revolution would curiously enough be pulled off, and a more complaisant government be set up, or, as many declare, the United States would openly assume control of the entire republic, either by martial law or by some form of territorial government. Be that as it may, the situation is entirely safe, providing too much is not taken for granted. The ways of the Latin Americans are not our ways, and the *entente cordiale* can best be preserved by our keeping a paving block close by to drop the hand on to, in case ordinary argument should need a point.

The Act of Congress which authorized the President to proceed with the construction of the canal placed almost unlimited power in his hands as to details of route, type and size of canal, the chief limiting clause which, it may be noted, leaves

much to his judgment, reading as follows: The canal "shall be of sufficient capacity and depth as shall afford convenient passage for the vessels of the largest tonnage and greatest draft now in use and such as may be reasonably anticipated."

In order to obtain the advantage of the best engineering advice upon the many general problems involved, the President appointed a board of consulting engineers, the members being eminent in their profession, both American and European. After a visit of inspection to the isthmus and due consultation the board made two reports, the majority one favoring a sea-level and the minority a lock plan, both reports, however, concurring in the other general features. After a long time the whole matter was referred to Congress. The latter body, after examinations and debates, voted in favor of the minority, or lock-level plan — the one under which work is now being prosecuted.

It would require very much more time than is now available to sum up even the various reasons which I believe justified the final decision in favor of a lock canal. I went to the isthmus as chief engineer, rather in favor of a sea-level plan, which I abandoned after personal study of the conditions. As I had reason to believe my influence was quite potent in the decision, I feel that this one service to the country is enough for a lifetime in helping to save the fatal consequences of a wrong conclusion, as I know a decision in favor of a sea-level canal would have been.

Briefly expressed is an extract from a report to the Canal Commission, of date January 26, 1906, as follows:

"The sum of my conclusions is, therefore, that, all things considered, the lock or high-level canal is preferable to the sea-level type, so-called, for the following reasons:

"It will provide a safe and quicker passage for ships, and therefore will be of greater capacity.

"It will provide, beyond question, the best solution of the vital problem of how safely to care for the flood waters of the Chagres and other streams.

"Provision is made for enlarging its capacity to almost any extent at very much less expense of time and money than can be provided for by any sea-level plan.

"Its cost of operation, maintenance, and fixed charges will be very much less than any sea-level canal.

"The time and cost of its construction will be not more than one half that of a canal of the sea-level type.

"The element of time might become, in case of war, actual or threatened, one of such importance that measured, not by years but by months or even days, the entire cost of the canal would seem trivial in comparison.

"Finally, even at the same cost in time and money for each type, I would favor the adoption of the high-level lock canal plan in preference to that of the proposed sea-level canal.

"I, therefore, recommend the adoption of the plan for an eighty-five-foot summit-level lock canal, as set forth in the minority report of the Consulting Board of Engineers.

"Very respectfully,

"JNO. F. STEVENS, *Chief Engineer.*"

To go back to the time when the United States took formal possession by purchase from the French company and by treaty with Panama: This commission, appointed by the President to supervise the work, proceeded to the isthmus, began the work of organization of the preliminaries and the thousand and one details naturally pertaining to such an enterprise, under the conditions of a tropical climate. The mention of the latter condition brings us directly to the underlying important feature of sanitation and the consequent good health of employees without which nothing but failure could result.

Probably no spot on earth previously to the year 1906 had — and it largely deserved it — a worse reputation for diseases of various kinds than Panama. It will never be known how many employees of all colors lost their lives during the French occupancy. Very little was known of modern sanitation, — at least very little was practiced by them, — and even if their finances had held out it is probable death and disease would have conquered them in the end. But by the knowledge our army medical men had gained in Cuba as to the true cause and means of preventing yellow fever, that white man's scourge of the tropics has been eliminated, and the percentage of malaria and malarial fevers has been reduced more than one half. Colon at the northern, and Panama at the southern, terminus of the canal, were up to 1907 two of the most forbidding, dirtiest, and, from a white man's point of view, unhealthiest places on earth. To-day, they are and have been for more than four years past, especially Panama, cleaner and more sanitary than the average American city; paved throughout, provided with modern sewerage and water systems, they are at once a tribute to the energy and intelligence of those Americans who made them possible, and a standing reproach to those Americans who for the sake of a little printed notoriety have so far prostituted themselves as to send forth to the world statements which were not only false but palpably known by themselves to be false when issued.

Recently I have noticed in local newspapers very flattering comments on the present conditions as regards streets, sewers and water supply in Colon and Panama.

These are all true, but I want to remark in justice to the engineers in civil life who designed and built these works and wrought these changes, that all this was done prior to the advent of the army engineers, and was not done by the latter, as stated by the articles in the press to which I have referred.

This work of sanitation and municipal improvements in these two cities has cost the United States a very large amount of money, which the treaty provides shall be repaid after a long term of years, and there is a reasonable probability we shall be so repaid, but if we are not, the value of this work to us will be fourfold of all that it cost, in the health and life of our employees.

The same careful attention to sanitation has been given to all parts of the zone where our employees, either whites or blacks, work or live; and to-day the health conditions of the Canal Zone are better than they are along lands in the United States bordering on the Gulf of Mexico, and it may be believed the zone is a preferable place of residence. The heat is not intense as measured by the thermometer, but the humidity is excessive, and without doubt the climate is a trying one on this account to the average person accustomed to the high latitudes. This objection is provided for, however, by the United States granting to all its employees coming from the United States a six-weeks' yearly leave of absence with pay. This provision, with the practice of ordinary good habits, will carry the average man along in good health, and as safe as he would probably be in the United States.

The Commission at Ancon, near Panama, and at Colon, has large and well-equipped hospitals, at which, free of charge, all its employees, white or black, are given the most modern medical care and treatment — all under the charge of experienced doctors and trained nurses. The privileges of these hospitals are not only free to all employees, but they are also compulsory, and as a result from month to month the sick and death rate of the zone per capita has been gradually decreasing, until now it compares favorably with that of the average American city. Certain diseases, like typhoid, diphtheria, etc., have never been prevalent there, and as far as yellow fever is concerned it is now simply a matter of the enforcement of strict quarantine regulations against other and less fortunate countries to keep the zone entirely free of it.

The government of the zone is administered by the Canal Commission through one of its members who acts as civil administrator, having direction of the courts, police force, schools, post-offices, customs and all the functions which go to make up a well-ordered government. Law and order are as well maintained and life and property as safe as in well-settled parts of the United States. There are three circuit court judges who sitting *en banc* form a supreme court. All the judicial and civil machinery has thus far worked smoothly, and it is believed that it is well adapted to serve the purpose for which it is created.

The length of the proposed canal, from deep water to deep water, will be about fifty miles, the width varying as below, these widths as noted being at the extreme bottom of the canal sections. From the Caribbean Sea, near Colon, 1 000 ft. for about seven miles to Gatun Dam and Locks; from Gatun Locks a minimum width of 1 000 ft. through Gatun Lake (to be formed by the Gatun Dam) over a distance of about 26 miles; thence about 2 miles of a width of 500 ft. to the north end of Culebra Cut; then 300 ft. wide for about 9 miles, to the locks of Pedro Miguel, the south end of the Culebra Cut; then through Lake Sosa, some 5 miles, 1 000 ft. minimum width, to the locks of La Boca; then 3 miles to deep water in the Pacific Ocean with a width of 1 000 ft. These dimensions are given in some detail as showing from their generous proportions that a fair rate of speed can at all places be maintained by ships while passing through the canal, excepting through the locks proper, which comprise but an insignificant portion of the entire distance.

A modification of the plans for locks and dams near the southern end of the canal has been made, which will be referred to later on.

A brief study of the map will show that owing to the peculiar twist of the isthmus near its narrowest part the actual direction of the canal is not east and west, as popularly supposed, but from northwest at the Atlantic end, to southeast at the Pacific end, and that, in fact, Panama, on the Pacific side, is 22 miles east of Colon, on the Atlantic side, so that the use of the terms north and south ends of the canal is entirely proper.

In formulating the plans for any canal at Panama the one great overshadowing engineering problem that had to be solved before success could be expected was the control of the flood waters of the Chagres River and its large tributaries. This river, rising in the mountains of the Darien country some one hundred or more miles east of the canal, flows almost directly

west, thence by an abrupt turn changes its course to the north and northwest, emptying into the Carribean Sea about five miles west of Limon Bay, in which the canal finds its northern terminus. Thus for nearly thirty miles the canal follows the valley of the Chagres River — a stream which fluctuates from a flow of 600 cu. ft. per sec. in the dry season, to nearly 110 000 in the rainy season.

At several points along this part of the river the valley narrows, and at one point (Gatun) it is less than 1½ miles in width, at an elevation of 100 ft. above sea level, and it is at this point, where suitable foundations have been found to exist, that the gigantic works known as the Gatun Locks and Dam were projected, and are now in course of construction. The dam is to be of earth, will be about 7 800 ft. long on top, 100 ft. in width on top, and one-half mile wide, or thick, at the bottom. It will be 135 ft. high, and will contain approximately 22 000 000 cu. yd. of material, the greater part of which will be placed by powerful hydraulic pumps, thus insuring solidity of construction that only nature under favorable conditions can rival. This material will be clay, with a very slight mixture of fine sand, an ideal material to produce, so placed, a mass comparable only to a mountain — one that will resist water, decay, earthquake or any known force of nature or man within imaginable limits.

The truly enormous proportions of this dam were a concession, and a lame one, by the Commission, to the fancied criticisms of the public as to the stability of a strictly earthen dam. It was my intention always, at the proper time, to reduce the section of the dam to reasonable limits, and I am pleased to know it has been done, and the fact remains that even now, as being built, it has a very large factor of safety, and will still contain a mere trifle — only about 17 000 000 cu. yd. of material.

This dam will, by closing up the valley of the Chagres River, form a lake of some thirty odd miles in length, as measured by the main valley, covering approximately an area of 140 square miles, really a vast inland fresh-water sea; the elevation of the water held by the dam being normally 85 ft. above the sea-level waters of the Atlantic Ocean, which will be brought to the locks by the 7 miles of open 1 000-ft.-wide channel mentioned above. On other very high ground, nearly in the center of the dam, will be constructed the necessary regulating works by which the height of the water in the lake will be controlled, storing it up for the dry periods, and allowing it to flow gradually away during the flood periods, as conditions may require.

These regulating works, and the main locks also, will rest their entire length and breadth on rock — not earth, not mud, but rock; really, a species of sand rock sufficiently hard to insure first-class foundations and to set at rest all fears of the stability of the works. That the character of these foundations is first class was known long ago to the people directly responsible for them, and had been amply proven by numerous borings and test-pits; but to satisfy a senseless clamor set up and encouraged by ignorant critics, the Secretary of War — in whose hands next to the President is the general direction of all canal affairs — took a committee of three of the best-known and ablest of our American engineers last year to Gatun. These gentlemen, after a thorough, personal examination, concurred in a report which fully confirmed all previous ones of the chief engineer, and which should have settled for all time the questions raised; but very recently the Commission has given out a statement — quite superfluous — that additional borings have been made, and that rock exists everywhere under the proposed locks, and a splendid foundation is assured — another case of the Dutch taking Holland.

The earthen dam will rest on a stratum of impervious clay, nearly 200 ft. thick, lying on the same kind of rock that the locks will rest upon. Altogether the foundations of both locks and dam are ideal, and all notions to the contrary can be dismissed from the mind.

The control of the flood waters of the Chagres is simple, and the plan can be easily understood by any one, whether engineer or not. It is accomplished by the formation of a lake into which the flood waters will pour at such distances from the sailing line of ships that these flood waters can be entirely ignored. Supposing the Willamette River rose in flood, and that the Columbia River, or rather its waters, extended ten miles up the Willamette, from thirty to fifty feet deep, the valley being from one and one-half to three miles wide. What effect, then, would the flood in the Willamette River have on a ship sailing on the Columbia, a mile away from the point where the river joined the Columbia? None whatever — the ship's people would not know that there was a flood, unless from some slight discoloration of the water. And this is all there is to it — simple of solution, like most problems, when subjected to the analysis of cold common-sense, and a remedy of like character applied.

Leaving the lake the line of the canal enters the famous Culebra Cut, which will be about nine miles in length, and is directly through the backbone of the Cordilleras, — the water-

shed between the Atlantic and Pacific oceans. The mountains along the line of the canal rise to an extreme height of some 1 200 ft. above the sea, and probably it was from some one of these peaks that Balboa first caught sight of the peaceful ocean, the waters of which ripple as calmly as the Bay of Naples and present a view at Panama which for loveliness is said to rival it.

The bottom of the canal prism in the Cut, allowing for the 40 ft. of water, will then be 45 ft. above sea level, the surface of the water being at the same elevation as that of Gatun Lake, or plus 85. At the highest point the top of the Cut was originally some 280 ft. above the bottom, but the French dug away some 120 ft., and there are about 120 ft. yet to go down. This figure, however, does not adequately express the relative amount of work to be done. When the United States assumed charge of the enterprise, changes in line, increases in width, a more proper adjustment of slopes, etc., which were made, all contributed to swell the total yardage to be moved. An approximate summary of the various items showed about 70 000 000 cu. yd. of excavation to be taken from the prism in Culebra Cut, of which probably 80 per cent. is rock, of different degrees of hardness, and this vast amount of material was not to be dug out and placed in waste banks immediately alongside of the excavation, but the greater part must be hauled miles by railway trains to find room for disposal.

The work of drilling, of loosening up by blasting, ready for the big steam shovels, while appalling, was only one feature; hundreds of miles of track must be laid, locomotives by the hundred, cars by the thousand, and all the myriad special adjuncts of shops and machinery requisite to repair and maintain — all such plant had to be created, and when I reached the zone in July, 1905, I think I may truly say I faced about as discouraging a proposition as ever presented itself to a construction engineer.

Passing to the south end of Culebra Cut the locks and dam at Pedro Miguel are reached. Here, by duplicate locks, with a lift or drop of 30 ft., as the case may be, the change from the 85-ft. level was to be made to the level of Lake Sosa, 55 ft. above the level of mean tide in the Pacific Ocean. The plan adopted in 1906 was to build two earthen dams at La Boca, near the shores of Panama Bay, closing up the valley of the Rio Grande in precisely similar manner to the plan adopted at Gatun, thus forming a lake 4 miles in length, giving a minimum depth of 45 ft. of water with a sailing channel not less than 1 000 ft. in width. In Sosa Mountain — an isolated rock butte — against which the

dams were to rest, two locks in flight, in duplicate, each with a drop of $27\frac{1}{2}$ ft., were to be constructed, thus delivering ships practically into a 3-mile sea-level channel, leading to deep water in Panama Bay and the Pacific Ocean.

Thus the waterway really was to consist of one stretch of canal; then of a long, wide deep lake (Gatun); then throughout a channel (Culebra Cut) of varying widths; then through a smaller lake; and finally through another channel into the waters of the Pacific Ocean. This was practically the plan of the minority of the Consulting Board of Engineers, but was later modified to this extent:

It was decided to build the dam and locks at the south terminus some three and one-half miles further inland, and thus to extend the sea-level section up and through what has been known as the proposed Lake Sosa. This — particularly if the press accounts are correct — is a wise move. For long months I fruitlessly sought by borings to discover suitable foundations for locks and dam at or near Miraflores, the point finally selected. Since that time, however, changes in the plans of the locks, having the effect of dropping the walls and bottom of the same, have rendered sites available now for these works that a year ago were not tenable; and, too, it is an open question whether such changes in the lock plans, if not altogether unnecessary and questionable, have not added millions to their cost, far in excess of any saving in changes of location, and have not added to their efficiency, economy, or safety of operation.

In regard to this change the writer quotes from the same report made by him to the Canal Commission, referred to previously, as of date January 26, 1906.

"As regards the plan and alignment of the canal at the Pacific end, I am still inclined to my former expressed opinion that, on account of the military and sanitary features, the location of all the locks at Miraflores and Pedro Miguel, instead of part of them at La Boca, with the necessary dam at the same place, will be found more satisfactory; but as the latter plan will cost about $6 000 000 less to construct than the former one I am ready to waive my views in favor of the latter plan, although simply on account of the difference in the estimated cost";

which shows that the matter was then seriously considered, and that "there is nothing new under the sun."

The first, or so-called Walker Commission, was unfortunate in many ways which are immaterial here. The second commis-

sion — the one I had to do with — was more fortunate in its make-up, but it had its limitations. When I reached Panama in July, 1905, conditions could have been much worse, but they were bad enough. No real start at any effective work on the canal proper had been made, no adequate organization had been effected, sanitary reforms were really just beginning, little new plant had been provided and little that was absolutely necessary had been ordered. In the organization which existed no coöperation was apparent, and no systematic plans, as far as I could discover, had been formulated towards the carrying out of the work along lines promising any degree of success. And — worse than all — over and above, in the diseased imagination of the disjointed force of white employees, hovered the angel of death, in the shape of Yellow Fever, a number of cases of which were then prevailing, and from which several deaths had occurred. What many of the intelligent men seemed to expect was an order from Washington to abandon the work and go home. To provide housing for this army, to properly feed, to instill into them faith in the ultimate success of the work, to weed out the faint-hearted and incompetent, to create an organization fitting to undertake the tremendous work, and to fill its ranks with the proper material, was a task of heroic proportions. No one will ever know, no one can realize, the call on mind and body which was made upon a few for weary months while all the necessary preliminary work was being planned and carried forward, and no attempt was or could be made to carry on actual construction until such preliminaries were well in hand. And the only gleams of light and encouragement were the weekly arrivals of newspapers from the States, criticising and complaining because the dirt was not flying.

While the French turned over to us square miles of engines, cars, dredges and tools of every description, very few of them were of any value, and those that were used were only used until proper modern ones could be substituted; but as time wore on, as new plant arrived and was put in service, as proper food and housing were provided, as improved health conditions prevailed, as the majority saw that — unconsciously, perhaps, to them — a real, effective organization, working steadily but surely towards a definite and intelligent end, had been made, the whole situation changed for the better; and that the organization was effective, the plant well designed, and all the preliminary work was fairly well done, is evident from the fact that the construction of the canal since the real beginning, with little addition

to plant already in hand or under order, or material change in organization, has gone steadily on, and in amount has surprised the friends and confounded the enemies of the enterprise.

I want here to express my confidence in and appreciation of Colonel Goethals and his corps of able assistants who are in charge of this work. I have always had an admiration for our army engineers, and I am sure if, as I have no doubt, the fighting arm of our country is equal in efficiency to the engineering arm, we shall all be very proud of the results in whatever they may undertake, be it war or canal building.

Reference has been made to the importance of the Panama Railroad to the work of construction. Lying as it does immediately along the line of the canal, it affords the only practicable means for disposing of the millions of yards of waste material coming from Culebra Cut. Huge systems of tracks have been planned and laid in the Cut on which are handled hundreds of work trains loaded by the steam shovels with rock and earth, these systems of work tracks being connected at proper intervals with the main tracks of the Panama Railroad over which the trains run to the dumping ground, or waste banks, some of the latter being 15 miles distant.

The rejuvenation of the Panama Railroad was one of the hardest problems that had to be met in getting ready to push the canal construction. It had but a single track, practically no sidings or station buildings, a worn-out telegraph line, no terminals worthy the name, and motive power and rolling stock that were obsolete twenty years before. While a fair amount of new equipment had been ordered, little or nothing had been done to place the road in proper shape to handle the heavy business suddenly thrown upon it. Traffic, both that pertaining to the canal and commercial, local and through, was nearly at a standstill; thousands of tons of through freight were piled in cars, warehouses and on docks, and some of these shipments had lain from three months to a year and a half in the hands of the railroad company, and in many cases even the shipping papers and records of this freight had been lost.

All these congested conditions had to be cleaned up, the road rebuilt, reorganized in its operating features and personnel, care being taken at the same time of a constantly increasing traffic. All this was accomplished, so that the Panama Railroad in 1907 was placed in a condition, both from a physical and operating standpoint, fit to compare favorably with the average of our best American roads.

The creation of Lake Gatun necessitated the relocation and rebuilding of some forty miles of the railroad to place it above the lake level, which work is already under way, and will be completed before the work on the canal proper is done. Meanwhile the road is handling the canal business, as well as the commercial business; the latter was, however, badly handicapped by the very inefficient service of the Pacific Mail Steamship Company, whose ships formed the connecting link between Panama, San Francisco and the various ports of call along the Central American and Mexican coast.

Among the great problems that had to be solved was the securing and care of the vast army of skilled and unskilled laborers, the clerical and supervising forces requisite to carry on the work. The skilled forces were, and still are, recruited in the United States by agencies established here at various points. At first much difficulty was experienced in securing the right class of men in the requisite numbers, owing to the bad reputation which the isthmus bore, and this trouble was needlessly continued long months by the malicious attacks through the press by some of our American writers, whose motives, to be charitable, can only be ascribed to a morbid desire for notoriety. By patient and intelligent efforts, however, the situation improved, until four years ago it became satisfactory, and to-day the supply of first-class material along the lines of clerical force and skilled labor is in excess of the demand. The high rate of wages paid, together with the other privileges enjoyed by these employees, make employment under the Commission usually much more attractive than any they can secure in the United States.

The supplying of the unskilled labor was much more perplexing and unsatisfactory. Practically all of this class of labor in the tropics has for years been drawn from one source, — the blacks living in the different islands in, and adjacent to, the Caribbean Sea; and it is largely from these islands that the present force of laborers is recruited.

Their value as laborers, however, is very low under any condition, and I soon found on taking charge of the work that if the canal was to be completed within any reasonable limit of time, or expense, some other source for obtaining labor must be developed, not only to obtain a better grade and surer supply, but to eliminate the sense of security these people possessed through the feeling that they had control of the situation by having a labor monopoly. Several plans were discussed and finally an

agent was sent to Europe, who, after some delay, succeeded in directing to the isthmus, through the various steamship companies, a stream of Gallegos, the people living in the Biscayan provinces of Spain, Italians and Greeks; so that for some time the labor situation has been well in hand as far as numbers are concerned.

The grade is low, and the consequent result will, of course, be a large increase in the cost of the canal as compared with what the work would cost if carried out where the best ordinary labor could be procured. The negroes are paid ten cents and the Europeans twenty cents per hour, in gold. There are some thirty odd thousand of the former and probably six thousand of the latter, and the net result is that, taking our best white labor here in the United States as a basis of comparison, a day's labor, by reason of lack of efficiency of the blacks, is costing the United States on the canal work at least three and one-half dollars, and this will swell the final cost of the canal many millions.

All employees, white and black, of every grade, are given, free of rent, with free lights and fuel, comfortable, furnished houses. The task of supplying all these wants was a tremendous one. While we took over from the French many hundreds of houses of various classes and capacities, all of them had to be rebuilt and made sanitary, and in addition new dwelling-houses and quarters by the thousands, hotels and eating-houses, hospitals, schoolhouses, court houses, post-offices, jails, commissary buildings, fire engine-houses, shops and railway buildings of every description, club houses, — and, indeed, the list alone is too long even to enumerate, — had to be provided.

On the pay-rolls of the building construction alone, for two years, were carried more than 4 000 men; and including buildings, docks, etc., there was used in 18 months by the speaker, over 80 000 000 ft. B.M. — equivalent to nearly 6 000 carloads — of lumber, brought from the Columbia River, Puget Sound and the Gulf States.

Then the problem of feeding this army, remembering that it was two thousand and more miles from its base of supplies, was a great one. After much deliberation, the plan of the Commission of supplying meals to all, excepting those married employees who preferred to keep house for themselves, was adopted, and it has been and is, despite criticism, a great success. Commissary and other needed supplies are sold to employees under carefully guarded regulations, generally as cheaply and in some cases cheaper than the same cost us right here in the United

States, and about the same class of meals is furnished in the Commission eating-houses for thirty cents as is served throughout the United States for fifty cents. Of course there are and will be complaints. There are complaints in our five-dollar-a-day hotels here, and there will be as long as time and human nature endure, but the facts are as stated. The record made by the Commission in housing and caring for these employees is one that can be pointed to with pride, and no one who was able to and would work has gone hungry. No Dooley can say, as on another occasion, "Well, the glorious war is over, and the byes are starving at Montauk, as they did at Tampa."

As to the length of time necessary to complete the canal: This depends upon many conditions, some of which may change so as to disarrange all calculations. Early in 1895 I went on record before congressional committees to the effect that the work should be done and the canal opened by January 1, 1915, and I still hold this opinion. As before stated, the limiting factors are Gatun Locks and Culebra Cut. No night work has yet been done at either place; at Culebra, while it is possible, it is not advisable; conditions are not such that economical night work there is practicable, nor is it necessary. But the past rate of progress in Culebra Cut cannot be maintained during the removal of the lower part of the prism for several reasons, but two to two and one-half years should be ample, and it is believed that the locks and dam at Gatun can be built in that time. They might be, by working night and day; which plan will probably be pursued. Conservatively, then, allowing proper time for contingencies, two to three years more should see the canal in operation.

You hear much from time to time about slides, and the probability of the completion of the canal being delayed by them. While these slides are large, and under ordinary circumstances would be formidable, they really offer but very little menace owing to their comparatively small size as compared to the volume of the work. I do not suppose from my knowledge of the situation that they will amount to three per cent. of the total volume of the cut, and there is not the slightest reason to think they will prove anything but a slight addition to the cost of the work.

Now, as to its probable cost: All estimates are guesswork, based upon experiences gained under conditions similar to the ones under consideration. Without entering into the various discussions of previous or present time, I believe that the estimate

of $360 000 000, recently made by Colonel Goethals, will fully complete the canal, as well as cover the cost of necessary adjuncts, such as government, sanitation, etc. However, changes in lock plans, as before mentioned, have added millions to the cost, and should not have been adopted, unless for better reasons than have yet been set forth publicly. In any case it may be taken as true, if any previous estimates of the cost of the lock type are proven to be too low, *as based on original plans*, that it is absolutely certain that estimates of the cost of a sea-level canal would have proven also to have been too low, to a very much more marked extent.

The most practical questions of all to be considered, and the correct answers to which time only can give, are: Of what benefit will this canal be to the people of the United States, who are mortgaging themselves to pay for it? and, Will it pay, measured in dollars and cents?

Taking then the two values, the military and the commercial: As far as the former is concerned, it undoubtedly will be of great value, but not to the extent hastily assumed. If the United States is to retain its place among the first-class powers, nothing appears to be clearer than that it must be as well armed as its neighbors; when they disarm, then we can, and not until then. Peace conferences are all right theoretically, but so far no evidence has been given that anything of value, as looking towards permanent peace, has evolved from them. Indeed, the last one at The Hague, to judge from reports, should rather have been named a "war conference," as it dealt mostly with ways of amending the existing rules so as to enable war to be made more easily. The United States must then maintain a big navy, and, it is believed, two of them, one on the Atlantic and one on the Pacific Ocean.

Nations nowadays when intending to go to war do not publish their intentions and wait for proposals; they begin to fight and declare war later on, as witness the recent Japanese-Russian fracas. As David Harum said, "Find out what the other fellow is going to do to you, and do it to him first" will be the policy, and this view is emphasized when yearly it becomes more evident that the future great international wars will be fought on sea and not on land.

With the Panama Canal completed it will take a modern war fleet moving as a unit at least seventeen days to steam from Hampton Roads to San Francisco, or vice versa; and seventeen days is a long time to wait when 13-in. shells are mussing up

one's front yard. No, the idea that a navy can be thrown from one ocean to another, like a hot potato from hand to hand, does not appeal to a practical mind, and I believe that a navy to be of value must be somewhere in the immediate vicinity of the trouble, which will come quickly if it comes at all.

And, too, as it is the improbable that generally happens at such times, supposing, in case of war with some of our Oriental neighbors, that the enemy's warships should quietly elude our one wandering tramp fleet, somewhere in the vast expanses of the Pacific Ocean, and they should capture the Panama Canal, and get control of our coal supply, and war materials. The people of our eastern coast have had one vision of a hostile fleet playing hide-and-seek on the Atlantic, and if memory serves correctly, their feelings and actions at the time did not indicate that they are anxiously looking for a similar experience. No, rest assured, our expenditures for a proper military program will not be lessened, but will rather be largely increased by the Panama Canal, and the necessity for fully protecting it in time of war, by naval as well as by land defenses.

The late Congress, after detailed debate, approved the policy of canal fortification, and the initial appropriation for the work was granted. It is to be hoped the work will be thoroughly done, and the great thoroughfare be placed without question beyond any probability of successful attack, regardless of peace compacts.

The question of the commercial value of the canal to the United States is one upon which individual judgment will vary greatly. Without assuming to take decided ground either pro or con, it may be pertinent to call attention to a few points that seem to bear directly on the matter, and which may at least serve to give food for thought to those who may be interested.

No exact records, of course, exist, but as nearly as can be determined not more than 5 per cent. of the population of the world live south of the equator, and not over $1\frac{1}{8}$ per cent. live in South America west of the Andes Mountains, and the great majority of these are people whose wants are primitive and whose products are insignificant. The great bulk of the people of South America live, and always will, east of the Andes, in Brazil, Argentine Republic, Uruguay and Paraguay, and all these people, both east and west, are bound by ties of race, of family, of business, to Europe; and east of the Andes Mountains the traffic will gravitate as surely, by reason of the immense navigable rivers and by the systems of railway now being con-

structed, toward, and to, the Atlantic Ocean, as an apple drops from a tree to the ground.

We need no Panama Canal to give us the cream of the business from Venezuela, the Guianas, Brazil, the Argentine Republic — do we get it? No. To-day, if you want to go to Brazil, or any country south of there, you will go first to some European port and take a ship from there to your destination. There is a vast empire which covers southern Ecuador, eastern Peru, all of Bolivia and western Brazil; probably 1 000 000 square miles in extent; unsurpassed in timber, mineral and agricultural wealth, and all practically lying in the watershed of the Amazon. This river is navigable by ocean ships to the heart of this country, and by light-draft vessels to the very foot-hills of the Andes Mountains. Railways already projected can and will be built eventually on water grades to connect with the heads of navigation on numerous streams, and the millions of tons of the products of this now virgin wilderness will drop down the Amazon by the cheapest form of transportation, and will have the world for a market. Nor can this business be forced up and over the high summits of the Andes Mountains to find shipping at the western South American ports. Traffic moves along the lines of least resistance, and only a temporary violation of natural laws can change what appears to be written as the future, the greater part, of South American commerce.

By reason of the canal we can expect nothing from Africa, little from Australia, and from the few scattered, insignificant (from a traffic standpoint), coral islands in the South Pacific Ocean. What, then, is left us? The trade between the two coasts of the United States; that of Hawaii, the Philippines, China and Japan. Now, what are we going to sell these latter people, and what will they buy from us that will be routed through the canal?

Coal? We hardly mine enough now to keep our factories and railroads going and our houses warm — and besides, our great undeveloped coal resources lie nearer to the Pacific Ocean than they do to the Atlantic or Gulf of Mexico.

Wheat? By ten years from now, with one half of the usual yearly increase in our population, unless we greatly improve our methods of agriculture, not one bushel of wheat will be exported from the United States; if it is, it will go by the way of our Pacific ports.

Lumber? This is a point I touch upon with diffidence, because of the intense local interest in lumber, and the expecta-

tions which have been raised by the belief of lower rates and enlarged market, consequent upon the opening of the canal. "When doctors disagree, who shall decide?" A very successful merchant and lumberman in the Gulf States told me that the trade of New Orleans, Mobile, etc., would be vastly increased when he and his neighbors could ship lumber via the canal to the west coasts of Central America and the United States. As railroad men would say, this looks like a "cross" haul, or "carrying coals to Newcastle."

I believe there is at this present moment lying at our docks in this city ready to sail, a ship which asked for lumber loading for New York in connection with the Panama Railroad, at a rate of 53 per cent. of the present railroad tariff to the same point. But I hear she is sailing with a load for canal construction at Panama, and nothing for New York — why, I have not learned.

Now, there are no purchasers of lumber, or any practical combination, on the Atlantic seaboard, who can take at once an entire shipload of the class of lumber that market demands. To do so would require the carrying of such enormous stocks that insurance, depreciation and current charges would cancel any saving in a cut of freight tariff. Besides, the class of lumber demanded by the eastern market will not stand the long sea voyage as deck load.

The carrying charge plus the canal tolls, the transfer at eastern docks from ship to rail, will inevitably confine the zone in which delivery of lumber can be profitably made via the canal to a narrow strip near the sea board, probably less than three hundred miles, where it will meet all rail shipments via our transcontinental lines.

The great market for our northwestern lumber will be in the vast, wealthy, agricultural and manufacturing basin of the Mississippi River and its tributaries, the purchasing power of which probably exceeds that of any district of like extent in the world. And this district will be reached by railroads and not canals.

What I have said in regard to lumber will apply, I think, to the distribution of many other of our local products. I believe the Panama Canal will be, on the whole, of probably more benefit to our northwest than any other segregated part of the United States. I believe it will help it, and anything that helps this country, anything that develops its resources, makes it wealthier and more powerful, helps the railroads, and that is the reason why I believe as I do as to the relations that should exist between

canals and railroads as common carriers. Together they are stronger and of more potent influence for the good of the country than either could be alone.

Iron and iron products? China has iron and coal to an extent at least equal to ours, and we can hardly hope to compete with her in her own natural markets in the face of her cheap labor, even if we could eliminate the cost of thousands of miles of transportation. Enough is known of the immense deposits of coal and iron in China to warrant the belief that with proper development — which is sure to come — of her manufacturing and transportation facilities along these lines, she will in the future be able to control the markets of the East, and possibly compete with us right here at home. She has already made steel rails.

Cotton and cotton products? Possibly we may along this line develop considerable trade, but we have to watch the cotton fields of Egypt and the Indies; and in the production of bread-stuff, Siberia will sometime rival if not outclass the United States and the Northwest Territory combined.

Hawaii will send us sugar, — some of it is now coming by way of the Tehauntepec Railway, recently completed.

What the Philippines can send us no one can now tell; possibly lumber, jute, sugar and coffee. So far they have given us nothing in return for vast expenditures, excepting a large and juicy lemon.

China and Japan send us silks, rice, matting, etc., but thus far the ships of the few lines that are plying between our Pacific ports and those of Japan and China have been run at a loss, excepting two foreign lines, which are heavily subsidized; and altogether the prospect of enormous shipments to us from China and Japan does not seem to be flattering, unless such shipments are made of raw material, like coal, iron and lumber.

The center of population of the United States is already a long distance west of the Allegheny Mountains, and the cost of transportation from the interior to the Atlantic, and thence over the long route by way of Panama, will undoubtedly be more for most kinds of shipments than the cost directly over the route by way of our Pacific ports.

And it must not be forgotten that land transportation in the United States has not come to a standstill. Our western railways are becoming more and more a factor, and our Pacific ports of greater importance yearly. Our business will demand, and political and other interests will give way, so that the necessary

funds can and will be secured to increase the capacity of the present, and to add new lines, so that as the production of our factories, our fields and our mines, increases, so will the means of transportation multiply, and the cost decrease, from the interior to the Pacific Ocean.

A study of the globe will reveal that as comparing the northern with the southern hemisphere the former contains within itself, by reason of its immensely larger land areas, by far the greater proportion of all that is of material value in the world. The great majority of all that is produced and of all that is consumed is by people living north of the Tropic of Cancer. Emigration and traffic, therefore, move largely on parallel lines of latitude, and not of longitude; and just so long as the demand continues as it is now for faster and faster transportation of every product, whether perishable or not, whether food products or those of iron, of copper, of wood, cotton, lumber or any other, you can figure out for yourselves what great tonnage the Panama Canal will handle in which the United States will be directly interested.

Unless we change our policy the canal will undoubtedly be of large benefit to Europe — much more than it will to the United States. Europe has its tentacles fastened upon the trade of western South and Central America — what there is of it. Let a naked native appear on the seashore in the tropics with a canoe-load, or a sack of cocoa, or of ivory nuts, or of copra, and the chances are good that in a couple of hours the smoke of a German steamer will show up on the horizon, and his purchaser is at hand — one who does business his way, who caters to his wants, and who does not try to sell him a warming-pan when he wants a pink shirt and a plug hat.

When we learn, as we may, that some form of reciprocity in our commercial laws, some encouragement of our merchant marine, such as is extended to its subjects by other countries, is a necessity, and when we realize — if we ever can — that our belief in our own infallibility and capacity is not shared by the rest of the world; when we find from bitter experience that conceit is not the only valuable asset in foreign trade, and that some concessions must be made to secure customers, then possibly, in the distant future, some of the millions going into the "big ditch" will come back to us, and the generations to come will grant to our memories the tribute of great foresight.

Assuming the correctness of the late estimate, the cost of the canal, exclusive of the interest charge during construction, will

be \$360 000 000; the yearly interest on this amount at three per cent. will be \$10 800 000. Add to this the cost of operation and maintenance, which has been figured at various times at about two and one-half millions, also a sinking fund of twelve million dollars yearly to provide at the end of thirty years an amount sufficient to retire the bonds.

Thus we shall have a charge of \$25 300 000 to be met by gross earnings which can come from only one source, that of tolls of passing traffic. The Suez Canal was thirty-six years in attaining a yearly traffic of 11 160 000 net tons. This amount of traffic applied to the Panama Canal, with a rate of toll of \$1.50 per ton, the highest rate yet suggested, would give a gross yearly revenue of \$16 740 000, — \$8 560 000 less than enough to meet fixed and operating charges in its thirty-sixth year.

The Suez Canal opened in 1870, showing a net tonnage the first year of 400 000, which gradually increased in thirty-six years to 11 160 000 net tons in 1906 (by net tonnage is meant the actual tonnage on which, under our rules of measurements, tolls would be collected). This would give an average for the thirty-six years at Suez of 5 300 000 tons.

Assuming, however, that the increase in tonnage at Panama would be fifty per cent. more than actually occurred at Suez, then the yearly average tonnage at Panama would be eight million tons, which, at \$1.50 per ton, would amount to twelve million dollars yearly earnings at Panama, which, taken from \$25 300 000, the theoretical yearly charges shown above, would leave a yearly deficit at Panama of \$11 300 000, which deficit in thirty-six years would amount to \$406 800 000, or \$46,000,000 more than the original cost of the canal; or, putting it another way, in thirty-two years we shall have been at the expense of rebuilding the canal.

It is understood, of course, that a refunding instead of a retirement of the bonds at their maturity would eliminate the necessity for a sinking fund. But on the other hand the assumed tonnage is undoubtedly too high, as is also the assumed rate of toll. It has been suggested, and with many arguments in its favor, that American ships be given free passage. If our merchant marine is ever to be re-established, it must be given some encouragement.

A direct subsidy is not likely to meet with popular approval, and free canal passage would be subsidy in an indirect form. The Suez Canal cost less than \$100 000 000, and costs little to operate and maintain, owing to its peculiar topographical features

and the dry climate, so it pays commercially. Its tolls are high, but the very nation which owns its shares subsidizes its ships, and thus indirectly gives them free or reduced tolls, and I think that such a policy would be a good one for the United States to adopt at Panama.

There is, however, a value in the Panama Canal to the United States, over and beyond its military and commercial value. The republics of South America are rapidly assuming a commanding position among the nations of the world, and in order that the United States may profit socially and commercially by natural intercourse with these republics we must take such steps as will impress upon them as well as upon the balance of the world, the fact that we are a great nation and will become greater and greater as time goes on. The formation of the Bureau of American Republics, with which organization you are doubtless well acquainted, has been a long step in the direction of a close social and commercial amalgamation between the two American continents, and the building of the canal by the United States is bound to add still further to our prestige with the South American people.

If the United States had not built the Panama Canal, some European nation would, or at least would have tried to do so, and the so-called Monroe Doctrine would have come still more forcibly to the front in the future than it has in the past. And with our world-wide expanding interests, which have taken on in the last few years such great development, it would seem that the construction of the canal by the United States had been forced upon us, and whether it pays or not in terms of dollars and cents, it will pay as a matter of sentiment. It has been well planned, is being well and honestly built, and I believe the verdict of the future, to which all of our acts must be submitted, will be that its conception and execution were for the best interests of our great and expanding country.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 1, 1912, for publication in a subsequent number of the JOURNAL.]

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLVII. DECEMBER, 1911. NO. 6.

ECONOMICAL DESIGN OF REINFORCED CONCRETE BEAMS.*

BY R. B. KETCHUM, MEMBER UTAH SOCIETY OF ENGINEERS.

[Read before the Society, December 20, 1910.]

IN the Transactions of the American Society of Civil Engineers, June, 1906, page 253, John S. Sewell, M. Am. Soc. C. E., wrote an article on the economical design of reinforced concrete floor systems, and this article with the discussion following is about all the literature on the above subject that I have been able to find. However, the *Engineering News*, 1907, Vol. I, pp. 203, 329, 215, 245, 686, also gives some information on the subject.

RECTANGULAR BEAMS.

In the following we use the straight line formula and the nomenclature as recommended by the Joint Committee on Concrete of the American Society of Civil Engineers, the American Society for Testing Materials, the American Railway Engineering and Maintenance of Way Association and Association of American Portland Cement Manufacturers.

* For copies of tables and diagrams here referred to but not reproduced in this article, also further elaboration of the subject by the author, the reader is referred to the School of Mines, University of Utah, by which the above will be published in the form of a bulletin early in 1912.

Nomenclature.

f_s = tensile unit stress in steel.
f_c = compressive unit stress in concrete.
E_s = modulus of elasticity of steel.
E_c = modulus of elasticity of concrete.
n = E_s divided by E_c.
M = moment of resistance or bending moment in general.
A = steel area.
b = width of beam.
d = depth of beam to center of steel.
k = ratio of depth of neutral axis to effective depth, d.
j = ratio of lever arm of resisting couple to depth, d.
jd = arm of resisting couple.
p = steel ratio (not percentage) $= \frac{A}{bd}$.

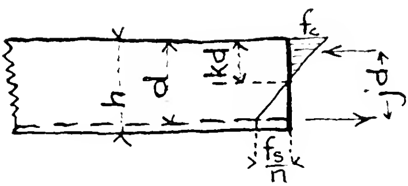


FIG. 1.

For position of neutral axis.

$$k = \sqrt{2pn + (pn)^2} - pn. \tag{1}$$

Arm of resisting couple,

$$j = 1 - \tfrac{1}{3}k, \tag{2}$$

$$f_s = \frac{kf_c}{2p}; \quad f_c = \frac{nf_c}{2}\left[\sqrt{\frac{2}{pn}+1}-1\right]; \quad f_s = \frac{M}{pjbd^2}; \quad f_c = \frac{2M}{jkbd^2}; \tag{3}$$

$$p = \frac{1}{2}\,\frac{1}{\frac{f_s}{f_c}\left(\frac{f_s}{nf_c}+1\right)}. \tag{4}$$

To determine the economical amount of steel to use in a rectangular beam we make the following assumptions:

1. Weight of concrete equals 150 lb. per cu. ft.
2. Cross section of beam is constant throughout its length.

3. Uniform load on the beam.

4. The depth of beam is fixed by such considerations as general proportions to resist shear, allowable clearances for head room, etc.

5. The value of $n=15$ is used throughout.

In order to facilitate the design of beams of various spans and various percentages of steel, we have constructed a double set of tables showing the safe net uniform load in pounds for beams one inch wide, the main body of the tables being based on $M=\frac{1}{8}Wl$, and the upper figures being for $M=\frac{1}{10}Wl$. Tables 1 and 2 are examples of tables of the first set, which are for

TABLE 1.

$p=0.002$ (1) TOTAL SAFE UNIFORMLY DISTRIBUTED LOAD IN POUNDS-BEAM ONE INCH WIDE

$f_s=15000$ $k=0.217$

$f_c=276$ $j=0.928$

$n=15$

Depth in inches h	d	Resisting moment in. lbs	Weight per lin. ft. lbs.	Span in feet 4	6	8	10	12	14	16	18	20	24
4	3	251	4.19	^{35} 25	^{10} 3		$M=\frac{1}{10}WL$ for figures shown thus.						
6	5	636	6.28	^{120} 91	^{58} 39	^{22} 8	$M=\frac{1}{8}WL$ except as noted						
8	7.	1364	8.38	^{240} 194	^{140} 102	^{75} 47	^{30} 7						
10	$8\frac{3}{4}$	2130	10.48	^{402} 313	^{233} 174	^{138} 94	^{72} 37	^{23}					
12	$10\frac{3}{4}$	3217	12.57	^{620} 486	^{371} 282	^{235} 168	^{143} 89	^{73} 28					
14	$12\frac{1}{2}$	4350	14.66	663	395	245	143	66	2				
16	$14\frac{1}{2}$	5853	16.77	908	550	354	223	124	44				
18	$16\frac{1}{2}$	7579	18.86	1188	729	481	317	195	97	14			
20	18	9020	20.95	1420	877	584	392	250	136	41			
22	20	11143	23.06	1755	1099	744	512	342	207	95			
24	22	13474	25.15	2145	1346	922	647	447	290	159	46		
26	24	16036	27.24	2564	1618	1118	797	564	382	232	104		
28	26	18820	29.35	3019	1915	1334	961	693	485	315	169	30	
30	28	21827	31.44	3512	2237	1567	1141	835	599	406	242	99	
36	$33\frac{1}{2}$	31243	37.73	5056	3245	2302	1706	1283	960	698	478	286	
42	$39\frac{1}{2}$	44437	44.02	7063	4562	3268	2456	1885	1452	1106	816	568	150
48	$45\frac{1}{2}$	57636	50.31	9405	6102	4100	3339	2598	2040	1597	1229	915	394

maximum unit stresses of $f_s=15\,000$ lb. per sq. in. and $f_c=600$ lb. per sq. in. The tables of the second set are for maximum stresses of $f_s=18\,000$ and $f_c=750$. For values below zigzag line, shear exceeds 100 lb. per sq. in.

TABLE 2.

⑩ TOTAL SAFE UNIFORMLY DISTRIBUTED LOAD IN POUNDS-BEAM ONE INCH WIDE

$p = 0.020$
$f_c = 600$
$f_s = 7960$

$k = 0.531$
$j = 0.823$
$n = 15$

$M = \frac{1}{10} WL$ for figures shown thus. $M = \frac{1}{8} WL$ except as noted.

Depth inches h	d	Resisting moment inch lbs.	Weight per lin. ft. lbs.	Span in feet 4	6	8	10	12	14	16	18	20	24	28	32	40
4	3	1180	4.37	228 / 179	138 / 105	88 / 64	54 / 34	29 / 13								
6	5	3278	6.53	656 / 520	416 / 325	289 / 221	208 / 153	149 / 104	104 / 65	32	3					
8	7	6424	8.83	1304 / 1036	839 / 661	598 / 464	447 / 340	341 / 252	259 / 182	127	79	36				
10	$8\frac{3}{4}$	10037	11.02	2047 / 1629	1327 / 1049	1057 / 748	726 / 559	565 / 426	443 / 324	242	163	115	15			
12	$10\frac{3}{4}$	15151	13.20	3103 / 2472	2025 / 1604	1471 / 1156	1130 / 878	893 / 683	716 / 536	419	323	241	104			
14	$12\frac{1}{2}$	20485	15.38	3352	2184	1584	1212	954	760	607	481	375	200	57		
16	$14\frac{1}{2}$	27565	17.67	4523	2957	2156	1660	1319	1065	866	704	565	341	162	9	
18	$16\frac{1}{2}$	35693	19.85	5870	3847	2815	2160	1746	1421	1179	965	792	515	294	109	
20	18	42478	22.03	6331	4537	3364	2610	2095	1716	1418	1176	975	650	396	180	
22	20	52441	24.32	8643	5581	4075	3253	2622	2157	1796	1504	1262	873	568	314	
24	22	63454	26.50	10470	6891	5076	3965	3207	2650	2220	1873	1585	1126	768	474	
26	24	75520	28.68	12471	8219	6065	4747	3851	3194	2690	2281	1944	1410	994	655	112
28	26	88630	30.97	14646	9661	7137	5598	4551	3786	3197	2725	2335	1719	1242	855	238
30	28	102789	33.15	16998	11221	8300	6520	5313	4430	3752	3210	2763	2060	1519	1080	387
36	$33\frac{1}{2}$	147127	39.80	24363	16108	11943	9410	7696	6449	5494	4733	4108	3132	2389	1791	860
42	$39\frac{1}{2}$	204555	46.45	33906	22449	16674	13172	10807	9091	7780	6740	5890	4567	3570	2775	1551
48	$45\frac{1}{2}$	271418	53.10	45024	29838	22133	17563	14440	12181	10453	9006	7385	6265	4375	3355	2400

Upon the above assumptions and from these tables we have designed a series of beams and tabulated the relative amounts of materials, and by applying cost prices show therefrom the relative costs of the various beams of equal strength. The tables are for different depths of beam; Table 3, for 12 in. depth, is an example. From these tables we platted curves showing the variation in cost with per cent. of steel, of which Figs. 2, 3, 4 and 5 are examples.

From the curves by using minimum points we are able to get at the law of variation of the economical per cent. of steel with the span of the beam as shown in diagrams of which Fig. 6 is an example.

By interpolation between diagrams of that type we are able to tabulate as in Table 4, the economical percentage of steel for all rectangular beams of the ordinary spans and depths for cost ratios of 30 and 60. We may interpolate for other cost ratios.

Table 4 does not, however, apply to slabs, as the breadth of the beam in this case is not variable, and for any depth of slab the problem consists in finding the amount of steel that will carry the given load, and there is no economy in using more steel than is required to carry the given load.

Conclusions. It is quite clear, from a study of the above diagrams and tables, that for certain cost ratios it is economical to use high percentages of steel even though the unit stress in the steel may be very low. The steel is not wasted by so doing, as it has the effect of lowering the neutral axis, thereby utilizing a greater portion of the concrete; for example, note that in Table 1 with 0.2 per cent. of steel, k equals 0.217, and that in Table 2 for 2.0 per cent. of steel, k equals 0.531, showing that in the use of a high per cent. of steel we use in this case more than twice the area of concrete as compared with the low per cent. of steel.

The use of high percentages of steel also has the following advantages:

1. Decreases the weight of the beam very materially.

2. Decreases the bond stress.

3. As the dangerous diagonal stresses are a function of the tension and shear combined, the low stresses in tension decrease the diagonal stresses.

4. Low working stresses in the steel provide a greater margin of safety against emergencies, as it has been shown by Professor

TABLE 3.

(28) Relative amounts of materials and relative costs

$h = 12''$
$f_s = 15000$
$f_c = 600.\ n = 15$

Per Cent. of steel	Span in Feet 8 Concr. Cu. Ft.	8 Steel Lbs.	14 Concr. Cu. Ft.	14 Steel Lbs.	20 Concr. Cu. Ft.	20 Steel Lbs.	24 Concr. Cu. Ft.	24 Steel Lbs.	⊗ Total cost in cents per lineal foot, Span in Feet 8	14	20	24
	×1359		×645		×310		×156					
0.2	b =	8.11							21.9 28.6 35.3			
	0.673	0.57										
0.4	b =	3.24	b =	5.33					9.9 12.6 15.2	15.2 19.5 23.8		
	0.269	0.45	0.43	0.75								
0.6	b =	2.05	b =	2.48	b =	5.85			6.4 7.6 8.9	7.6 9.6 11.6	18.3 23.1 28.0	
	0.170	0.43	0.20	0.52	0.486	1.23						
0.8	b =	1.57	b =	1.72	b =	2.36	b =	10.4	5.2 6.5 7.8	5.6 7.0 8.4	7.9 9.8 11.8	35.7 44.3 52.9
	0.130	0.44	0.14	0.48	0.196	0.66	0.86	3.31				
1.0	b =	1.46	b =	1.56	b =	1.97	b =	4.11	5.1 6.3 7.5	5.2 6.4 7.6	7.0 8.6 10.2	14.5 17.9 21.3
	0.121	0.51	0.12	0.55	0.163	0.69	0.34	1.44				
1.2	b =	1.37	b =	1.44	b =	1.71	b =	2.78	5.0 6.2 7.3	5.1 6.2 7.3	6.5 7.9 9.3	10.4 12.7 15.0
	0.114	0.53	0.11	0.61	0.142	0.72	0.23	1.17				
1.4	b =	1.30	b =	1.36	b =	1.56	b =	2.23	5.1 6.2 7.3	5.3 6.4 7.5	6.2 7.5 8.7	9.0 10.9 12.8
	0.108	0.64	0.11	0.66	0.129	0.77	0.19	1.09				
1.6	b =	1.25	b =	1.30	b =	1.44	b =	1.86	5.2 6.3 7.3	5.5 6.6 7.7	6.0 7.2 8.3	7.6 9.1 10.6
	0.104	0.70	0.11	0.73	0.119	0.81	0.15	1.04				
1.8	b =	1.21	b =	1.25	b =	1.36	b =	1.68	5.3 6.3 7.3	5.4 6.4 7.4	6.0 7.1 8.2	7.3 8.7 10.1
	0.100	0.76	0.10	0.79	0.113	0.86	0.14	1.06				
2.0	b =	1.18	b =	1.20	b =	1.28	b =	1.50	5.4 6.4 7.4	5.5 6.5 7.5	5.9 6.9 8.0	6.7 7.9 9.1
	0.098	0.83	0.10	0.84	0.106	0.90	0.12	1.05				
2.5	b =	1.11	b =	1.13	b =	1.17	b =	1.29	5.7 6.6 7.5	5.7 6.6 7.5	6.0 7.0 7.9	6.6 7.7 8.8
	0.092	0.97	0.09	0.99	0.097	1.02	0.11	1.13				
3.0	b =	1.06	b =	1.07	b =	1.09	b =	1.14	5.9 6.8 7.7	6.1 7.0 7.9	6.1 7.0 7.9	6.3 7.2 8.1
	0.088	1.11	0.09	1.12	0.091	1.14	0.09	1.20				
4.0	b =	1.00	b =	1.00	b =	1.00	b =	1.00	6.7 7.5 8.3	6.7 7.5 8.3	6.7 7.5 8.3	6.7 7.5 8.3
	0.083	1.40	0.083	1.40	0.083	1.40	0.083	1.40				

× Assumed total uniformly distributed net load

⊗ The three values of cost correspond to the cost prices 30¢, 40¢ & 50¢ per cu. ft. of concrete. 3¢ per lb for steel used throughout.

b = width of beam in inches to carry given net load.

Amounts of materials are for beam of width "b"

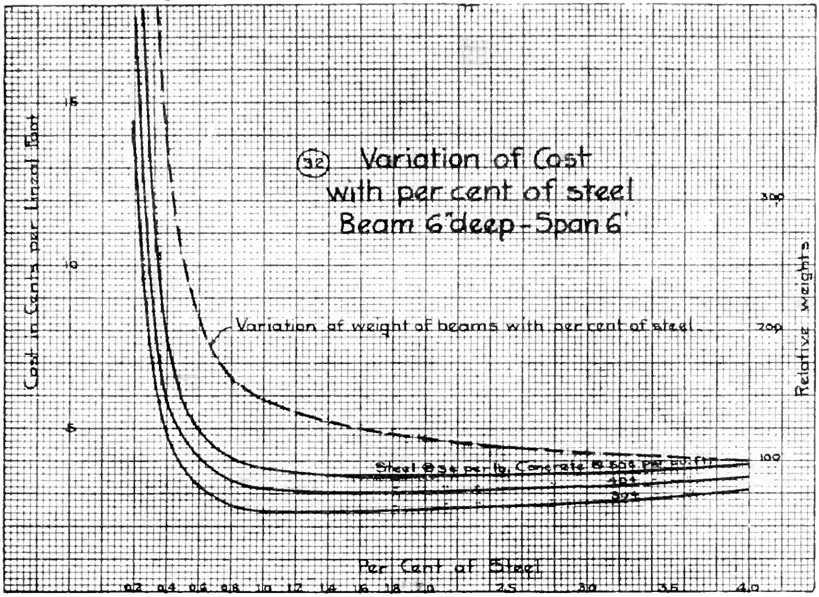

(32) Variation of Cost
with per cent of steel
Beam 6" deep - Span 6'
Variation of weight of beams with per cent of steel
Steel @ 3¢ per lb. Concrete @ 50¢ per cu. ft.
40¢
30¢
Cost in Cents per Lineal Foot
Relative weights
Per Cent of Steel
15
10
5
300
200
100
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.5 3.0 3.5 4.0

FIG. 2.

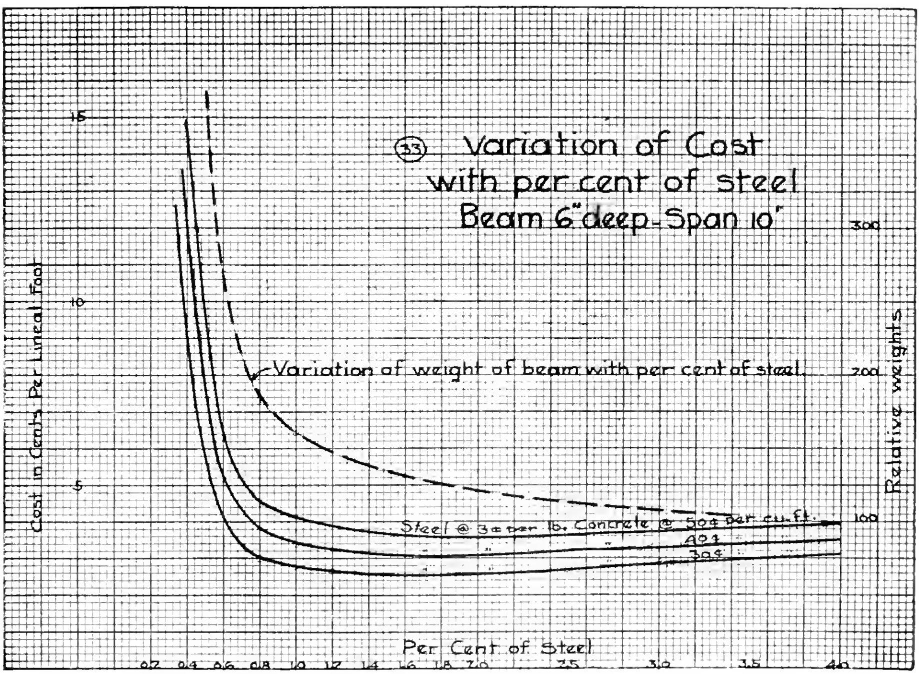
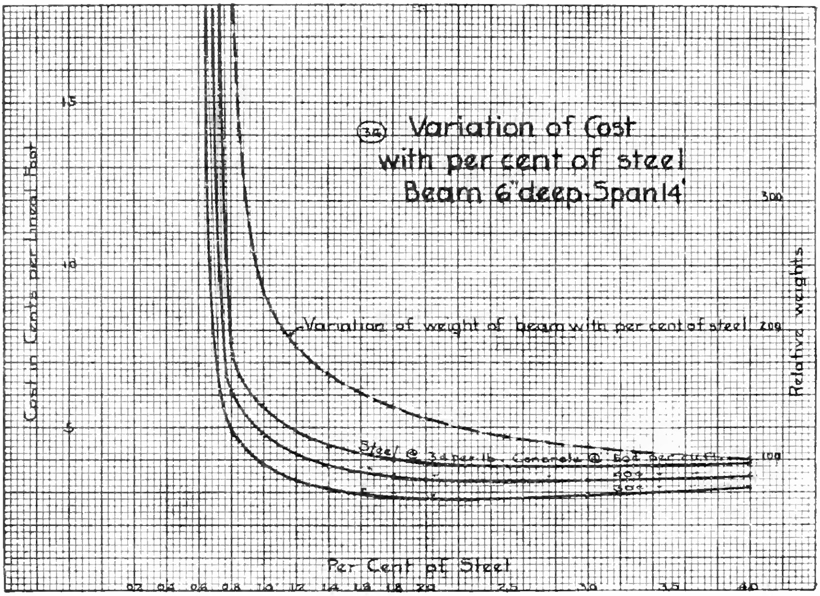
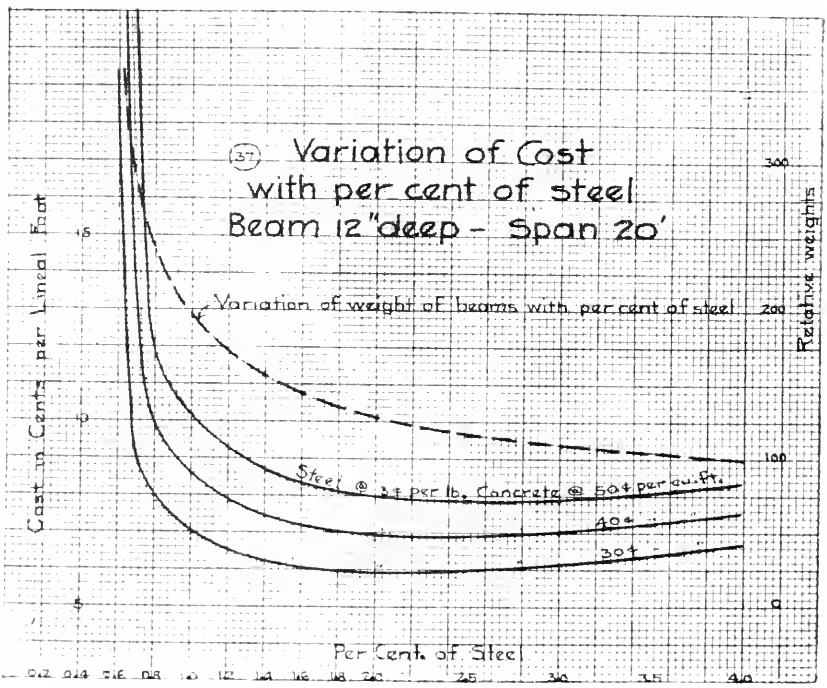

(33) Variation of Cost
with per cent of steel
Beam 6" deep - Span 10'
Variation of weight of beam with per cent of steel
Steel @ 3¢ per lb. Concrete @ 50¢ per cu. ft.
40¢
30¢
Cost in Cents Per Lineal Foot
Relative weights
Per Cent of Steel
15
10
5
300
200
100
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.5 3.0 3.5 4.0

FIG. 3.



(34) Variation of Cost with per cent of steel Beam 6" deep. Span 14'
Variation of weight of beam with per cent of steel
Steel @ 3¢ per lb. Concrete @ 50¢ per cu. ft.
40¢
30¢
Cost in Cents per Lineal Foot
Relative weights
Per Cent of Steel
15
10
5
300
200
100
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.5 3.0 3.5 4.0

FIG. 4.



(37) Variation of Cost with per cent of steel Beam 12" deep - Span 20'
Variation of weight of beams with per cent of steel
Steel @ 3¢ per lb. Concrete @ 50¢ per cu. ft.
40¢
30¢
Cost in Cents per Lineal Foot
Relative weights
Per Cent. of Steel
15
10
5
300
200
100
0
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.5 3.0 3.5 4.0

FIG. 5.

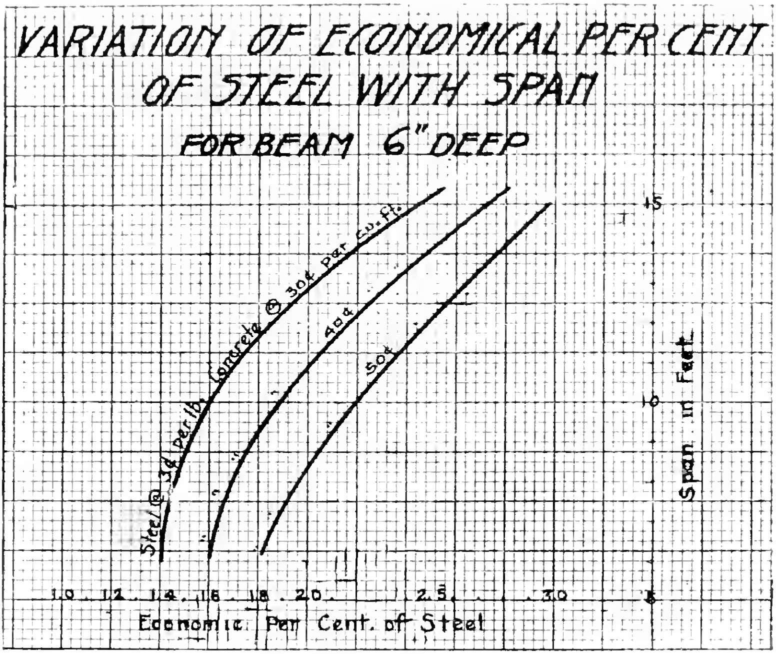


Fig. 6.

Talbot and others that with less than 1.5 per cent. of steel we cannot expect to develop the full strength of the beam.

5. High unit stresses in the steel always call for large deformations, which in turn will cause the small cracks which are described by all the experimenters to open wider than they would with low steel stresses, thereby increasing the possibility of corrosion of the steel.

6. Low deformations in the steel would also necessarily give low deflections for the entire beam, which would, of course, be desirable.

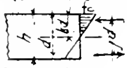
In regard to conclusion No. 1, we may say further that the dotted line shown on each of the diagrams of the type of Figs. 2, 3, 4 and 5 shows the variation of the weight of the beam with the per cent. of steel. For example, on Fig. 5, a beam 12 in. deep, span 20 ft., with 1.0 per cent. of steel, will weigh just twice as much as a beam of the same strength, same depth and span with 4.0 per cent. of steel, and the beam with 4.0 per cent. of steel will be the cheaper, the most economical per cent. of steel for this particular beam being about 1.7 per cent. for a cost ratio of 60.

TABLE 4.

(55) ECONOMICAL PER CENTAGES OF STEEL FOR RECTANGULAR BEAMS

Depth-ins h	d	4	6	8	10	12	14	16	18	20	22	24	26	28	30	35	40
6	5	1.2	1.2	1.2	1.3	1.5	1.9	2.4									
		1.8	1.8	1.9	2.2	2.5	2.7	3.2									
8	7	1.2	1.2	1.1	1.2	1.3	1.6	2.0	2.5	3.0							
		1.8	1.8	1.8	1.9	2.1	2.3	2.7	3.2	3.8							
10	$8\frac{3}{4}$	1.2	1.2	1.1	1.1	1.2	1.3	1.6	1.9	2.4	2.9	3.4					
		1.8	1.8	1.7	1.6	1.7	1.8	2.1	2.6	3.1	3.6	4.1					
12	$10\frac{3}{4}$	1.2	1.2	1.0	1.0	1.0	1.0	1.1	1.5	1.7	2.1	2.5	2.8	3.3			
		1.8	1.8	1.6	1.4	1.3	1.3	1.6	2.1	2.5	2.9	3.4	3.6	4.0			
14	$12\frac{1}{2}$	1.2	1.2	1.0	1.0	1.0	1.0	1.1	1.3	1.7	1.9	2.3	2.5	3.0	3.6		
		1.8	1.8	1.6	1.4	1.4	1.4	1.6	2.1	2.4	2.8	3.1	3.3	3.7	4.3		
16	$14\frac{1}{2}$	1.1	1.1	1.0	1.0	1.0	1.0	1.1	1.2	1.6	1.7	2.1	2.3	2.7	3.1	3.7	
		1.7	1.7	1.6	1.4	1.4	1.5	1.6	2.0	2.3	2.6	2.8	3.0	3.4	3.8	4.3	
18	$16\frac{1}{2}$	1.1	1.1	0.9	1.0	1.0	1.0	1.1	1.2	1.5	1.6	2.0	2.1	2.4	2.6	3.2	4.0
		1.7	1.7	1.6	1.4	1.5	1.5	1.6	2.0	2.2	2.4	2.6	2.7	3.1	3.4	3.9	4.7
20	18	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.1	1.4	1.6	1.8	1.9	2.1	2.2	2.7	3.5
		1.6	1.6	1.5	1.4	1.5	1.5	1.6	1.9	2.1	2.2	2.4	2.5	2.8	3.0	3.8	4.5
22	20	1.0	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.3	1.5	1.6	1.7	1.8	2.0	2.3	3.0
		1.6	1.5	1.5	1.5	1.6	1.6	1.7	1.8	1.9	2.1	2.2	2.3	2.5	2.7	3.7	4.3
24	22	1.0	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	2.0	2.6
		1.6	1.5	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.9	2.0	2.1	2.3	2.5	3.6	4.1
26	24	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	2.0	2.5
		1.6	1.5	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.9	2.0	2.1	2.3	2.5	3.4	3.9
28	26	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	2.0	2.5
		1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.8	1.8	1.9	1.9	2.0	2.2	2.4	3.2	3.7
30	28	1.1	1.0	1.0	1.0	1.0	1.0	1.1	1.2	1.2	1.3	1.3	1.4	1.5	1.6	2.0	2.4
		1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.8	1.8	1.9	2.0	2.2	2.3	3.1	3.5
32	30	1.1	1.1	1.1	1.0	1.0	1.0	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.5	1.9	2.4
		1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	2.1	2.2	2.9	3.3
34	32	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.5	1.9	2.3
		1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	2.1	2.1	2.7	3.2
36	$33\frac{1}{2}$	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.5	1.9	2.3
		1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	2.0	2.1	2.6	3.1
38	$35\frac{1}{2}$	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.5	1.9	2.1
		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.8	1.8	1.9	2.0	2.0	2.4	2.9
40	$37\frac{1}{2}$	1.1	1.0	1.0	1.0	1.0	1.0	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.8	2.0
		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.8	1.8	1.8	1.9	2.0	2.3	2.7
44	$41\frac{1}{2}$	1.0	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.7	1.8
		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2.1	2.3
48	$45\frac{1}{2}$	1.0	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.6	1.8
		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.8	2.0	2.1

NOTE: These values obtained by designing beams & comparing actual quantities of steel & concrete & applying cost prices to same: max $f_c = 600$ lbs.



$$n = \frac{E_s}{E_c} = 15$$

NOTE Use upper row of figures for cost ratio of 60
Use lower row of figures for cost ratio of 30
Interpolate for other values of cost ratio.

$$\text{Cost Ratio} = \frac{\text{Cost of Cu. Ft of Steel}}{\text{Cost of Cu. Ft of Concrete}}$$

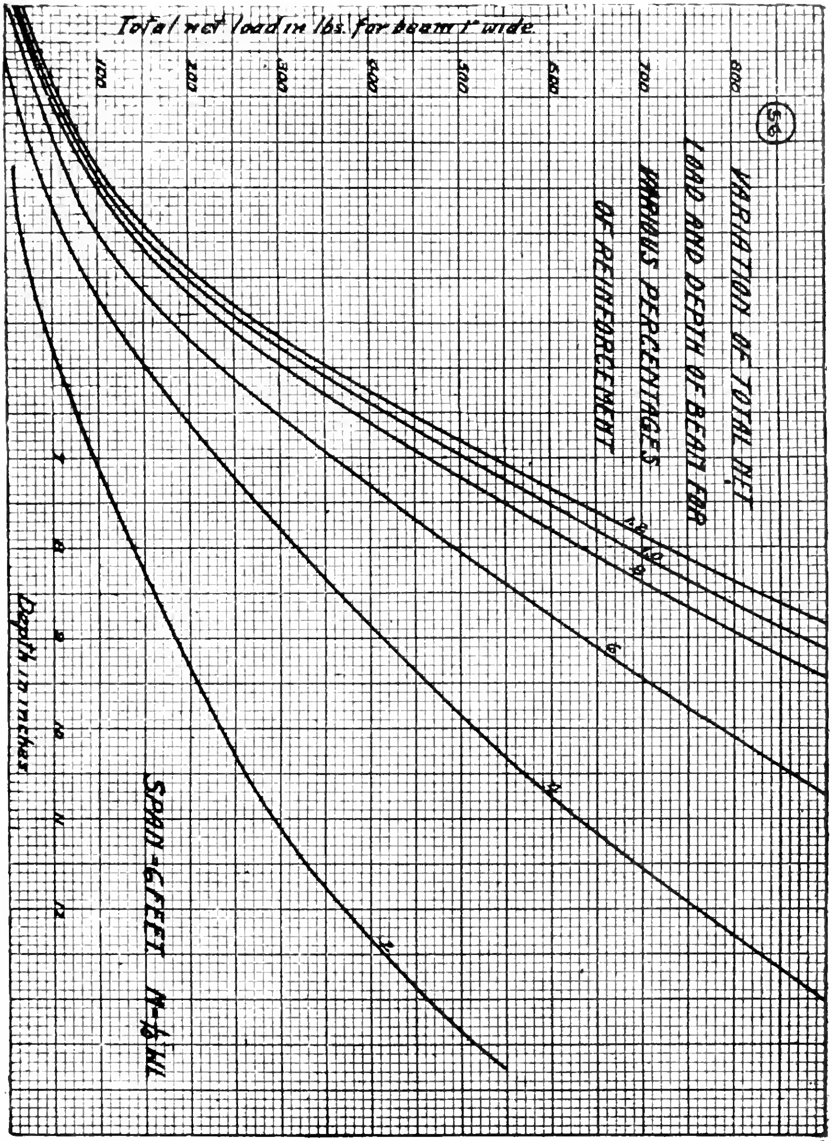

Total net load in lbs. for beam 1" wide
1000
2000
3000
4000
5000
6000
7000
8000
VARIATION OF TOTAL NET LOAD AND DEPTH OF BEAM FOR VARIOUS PERCENTAGES OF REINFORCEMENT
Depth in inches
SPAN = 6 FEET M = 1/8 WL

Fig. 7.

TABLE 5.

Slabs.

57 Relative Amounts of Material and Relative Costs. Span 6 ft.

$f_c = 600$
$f_s = 15000$
$n = 15$
$M = \frac{1}{10} WL$

Load = 100 Lbs/Lr. Ft. = 200 Lbs./□ Ft.

Percent of Steel.	Depth in inches	Concrete Cu Ft/□ Ft	Steel Lbs/□ Ft	Cost of Steel. @ 3¢	Cost of Concrete @ 25¢	Total Cost
.2	7.1	.592	.48	1.4	14.8	16.2
.4	5.1	.425	.64	1.9	10.6	12.5
.6	4.5	.375	.82	2.5	9.3	11.8
.8	4.0	.333	.94	2.8	8.3	11.1
1.0	3.9	.325	1.13	3.4	8.1	11.5
1.2	3.8	.317	1.26	3.8	7.9	11.7

Load = 200 Lbs/Lr. Ft. = 400 Lbs./□ Ft.

Percent of Steel.	Depth in inches	Concrete Cu Ft/□ Ft	Steel Lbs/□ Ft	Cost of Steel. @ 3¢	Cost of Concrete @ 25¢	Total Cost
.2	9.3	.775	.65	2.0	19.3	21.3
.4	6.6	.550	.88	2.6	13.7	16.3
.6	5.7	.475	1.11	3.3	11.8	15.1
.8	5.2	.433	1.31	3.9	10.8	14.7
1.0	5.0	.417	1.56	4.7	10.4	15.1
1.2	4.9	.408	1.83	5.5	10.2	15.7

Load = 400 Lbs/Lr. Ft. = 800 Lbs/□ Ft.

Percent of Steel.	Depth in inches	Concrete Cu Ft/□ Ft	Steel Lbs/□ Ft	Cost of Steel. @ 3¢	Cost of Concrete @ 25¢	Total Cost
.2	12.3	1.025	.87	2.6	25.6	28.2
.4	8.9	.742	1.23	3.7	18.5	22.2
.6	7.3	.608	1.47	4.4	15.2	19.6
.8	6.6	.550	1.75	5.3	13.7	19.0
1.0	6.4	.533	2.11	6.3	13.3	19.6
1.2	6.3	.525	2.19	7.5	13.1	20.6

As it often occurs that it is desirable to make the depth of a beam a minimum even at greater cost, we have thought diagrams Figs. 2, 3, 4, 5, etc., would serve as an accurate guide as to just what effect an increase or a decrease in the depth would have making it necessary to use more or less steel for any given case to carry a given load. Or perhaps we should say these diagrams show just what effect a change in the amount of steel has on the total cost. If we use a larger amount of steel than that shown to be the economical amount for a beam of that span and depth we can see readily how far we are from the point of economy and can tell what the ultimate difference in cost would be.

Slabs.

In order to get at the most economical design of slabs for various loads and spans, we first construct diagrams for various spans similar to Fig. 7, these diagrams being made up from the information in tables of the first set above mentioned, as Tables 1 and 2.

From Fig. 7 we make Table 5, showing the relative amounts of material and relative costs, varying the depths and the amounts of steel to conform to a given load per sq. ft. For

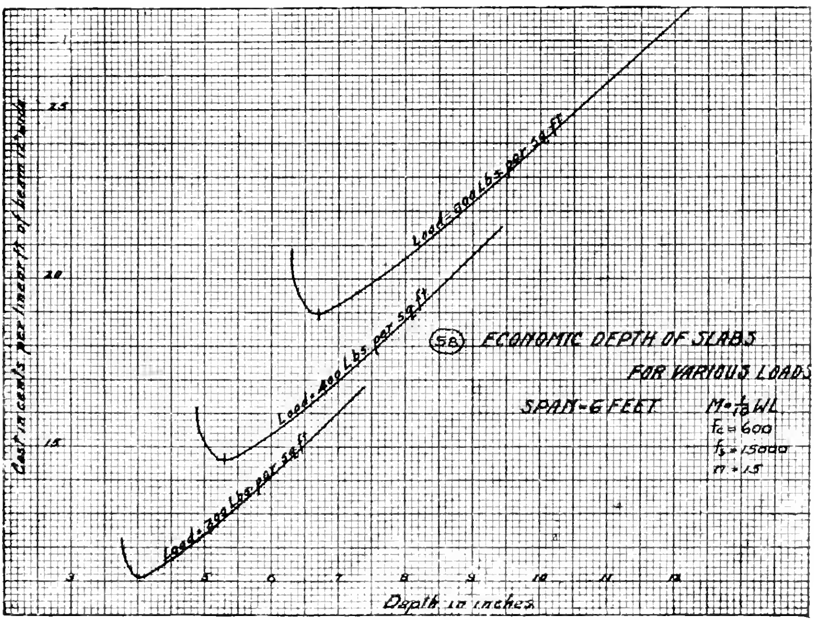


FIG. 8.

example, for a superimposed load of 200 lb. per sq. ft. on a span of 6 ft., we may use 0.2 per cent. of steel, depth of 7.1 in., or 0.4 per cent. of steel, depth 5.1 in., and so on to 1.2 per cent. of steel with a depth of 3.8 in.

Tabulating these results and applying cost prices we are able to plot the cost curves as shown on Fig. 8. These curves show very decided minimums for economical depths for the various loads.

In a similar manner we have made diagrams and tables for other spans, and from the curves similar to Fig. 8 we are able to get at the law of variation of economical depth for the various loads and cost ratios. We, therefore, construct Fig. 9, from the

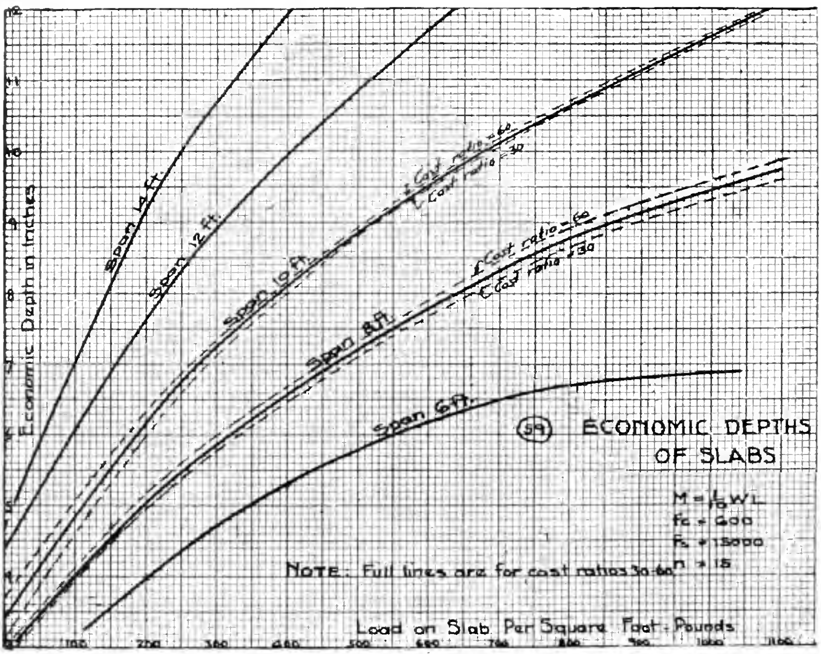


FIG. 9.

minimum points on the curves of Fig. 8. We apply cost ratios of 30 and 60 to Table 5 and similar tables, and from these results find that the variation of economic depth between these cost ratios is slight. The dotted lines show the economic depth curves for the two ratios and the full lines show the average between the two cost ratio curves. Noting that we should

ordinarily want the depth only to the nearest ¼ in., the solid lines would, therefore, be sufficiently accurate for any cost ratio between 30 and 60.

From curves in Fig. 9, we are now able to tabulate the economic depth for any span and any load. As these depths are taken to the nearest ¼ in., it now remains for us to get the exact amount of steel required to hold the given load.

TABLE 6.

ECONOMIC DEPTH OF SLAB AND CORRESPONDING PER CENT OF STEEL

LOAD		5	6	7	8	9	10	11	12	13	14 SPAN IN FEET
25	depth in inches	2.0	2.25	2.50	2.75	3.25	3.50	4.0	4.5	4.75	5.25
	per cent of steel	0.62	0.65	0.70	0.74	0.70	0.70	0.80	0.78	0.82	0.80
50		2.25	2.50	2.75	3.25	3.75	4.25	4.75	5.25	5.5	6.0
		0.65	0.75	0.82	0.75	0.73	0.78	0.74	0.71	0.80	0.80
75		2.50	2.75	3.25	3.75	4.25	4.75	5.0	5.5	6.0	6.5
		0.65	0.78	0.68	0.74	0.78	0.75	0.90	0.91	0.87	0.85
100		2.75	3.0	3.50	4.25	4.5	5.0	5.5	6.0	6.25	6.5
		0.65	0.78	0.72	0.71	0.90	0.85	0.85	0.85	0.93	0.70
150		3.0	3.5	4.25	4.75	5.25	5.75	6.25	6.75	7.5	8.0
		0.70	0.70	0.73	0.74	0.76	0.78	0.80	0.85	0.77	0.82
200		3.50	4.25	4.75	5.25	5.75	6.25	6.75	7.75	8.5	9.25
		0.61	0.66	0.68	0.73	0.78	0.81	0.90	0.72	0.72	0.77
300		4.25	4.75	5.25	6.0	6.5	7.25	8.0	9.0	10.0	11.0
		0.72	0.70	0.80	0.75	0.84	0.80	0.79	0.75	0.73	0.67
400		4.5	5.25	6.0	6.5	7.25	8.0	9.0	10.0	11.0	12.0
		0.71	0.71	0.71	0.81	0.83	0.85	0.78	0.78	0.74	0.72
500		5.0	5.75	6.5	7.25	8.0	9.0	10.0	11.0	12.0	
		0.65	0.78	0.72	0.75	0.79	0.78	0.78	0.76	0.73	
600		5.25	6.0	7.0	7.75	8.75	9.5	10.5	11.75		
		0.70	0.76	0.73	0.73	0.78	0.89	0.86	0.77		
700		5.5	6.5	7.5	8.5	9.25	10.25	11.5			
		0.73	0.71	0.70	0.71	0.80	0.83	0.76			
800		5.75	6.75	7.75	8.75	9.75	10.75	11.75			
		0.75	0.75	0.75	0.75	0.85	0.85	0.88			
900		6.0	7.0	8.0	9.0	10.25	11.25				
		0.77	0.79	0.80	0.88	0.85	0.88				
1000		6.25	7.25	8.5	9.5	10.75	11.75				
		0.76	0.80	0.76	0.87	0.82	0.88				

$f_s = 15000$-max
$f_c = 600$-max
$n = 15$
$M = \frac{1}{10} WL$

Upper row of figures gives depth in inches
Lower row of figures gives required per cent of steel.
Load given = pounds per sq. ft superimposed load.
Depths given are total depths of slab = h
When $h < 4''$, center of steel is ¾" above bottom of slab.
" $h =$ or $> 4''$ and $< 10''$ " " " 1" " " " "
" $h =$ or $> 10''$ and $< 12''$ " " " $1\frac{1}{4}''$ " " " "
The above depths are economic depths for cost ratios between 30 & 60

When the strength of the slab depends on the steel, this problem leads to a third degree equation. When the strength depends on the concrete, we have the relation —

$$k = 1.5 - \sqrt{2.25 - \frac{6M}{f_c d^2}}.$$

Having the value of k, we can readily get p from the relation —

$$P = \frac{k^2}{2n(1-k)}.$$

TABLE 7.

j=0.885 k=0.344 n=15

p=0.006
f_s=15000
f_c=523

(61) SLABS
TOTAL SAFE LOAD IN POUNDS PER SQUARE FOOT
$M = \frac{1}{10}WL$

Depth in inches h	d	Resisting moment inch lbs. 1-in wide	Weight per sq ft lbs	Span in feet 4	5	6	7	8	9	10	11	12	13	14
2	1¼	124	25.4	54	24	8								
3	2¼	403	38.2	213	122	74	45	24	11	2				
4	3	717	50.8	399	234	148	94	62	37	20	9	0		
5	4	1275	63.5	732	446	290	197	136	93	64	41	24	12	2
6	5	1992	76.2	1170	722	476	330	234	169	122	89	63	43	26
7	6	2868	89.0		1058	708	495	360	265	198	149	110	82	58
8	7	3905	102.0			982	694	407	381	288	221	169	129	97
9	8	5100	114.5			1302	925	682	516	396	308	240	188	147
10	8¾	6101	127.2					825	627	485	378	297	234	185
11	9¾	7574	140.0					1042	795	618	485	386	309	246
12	10¾	9209	152.5						1085	768	610	486	393	317

However, a more rapid solution of this problem is made by use of tables similar to Table 7, from which we readily interpolate the exact amount of steel required. These values for the required amount of steel for the slab of proper depth are shown in Table 6.

Hence, we have in Table 6 the most economical slab completely designed for any given load and span. Similar tables

could be made for unit stresses corresponding to any desired specification. However, in the above we have taken no account of the possible saving on the columns and girders of the structure that might be effected by using somewhat thinner slabs with more steel, thereby decreasing the dead load.

T-Beams.

When T-beams act as part of the monolithic floor, as is nearly always the case, the slab forming the flange of the beam, the problem of economical design is simplified from the fact that the slab portion of the beam does not enter into the cost of the beam. However, we have no general solution for this problem similar to that given above for the slabs and rectangular beams.

Considering only the materials in the stem of the beam, the cost will decrease as the depth increases, but as it is usual to figure the entire shear resisted by the web or stem, the minimum area of stem is fixed by the shear. Where clearances for headroom need not be considered, the maximum depth that should be considered would be that which gives a stem approximately three times its width for depth of stem below the bottom of slab. This would give the cheapest beam. However, it is seldom that clearance for headroom need not be considered. The saving in headroom is often a very valuable consideration, and, therefore, the depth is really fixed and the beam of minimum cost is the beam with a minimum cross section to resist shear and provide ample spacing for the rods.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by February 1, 1912, for publication in a subsequent number of the Journal.]

POSSIBILITIES FOR THE AMERICAN ENGINEER IN SOUTH AMERICA.

By A. R. Vejar.*

[Read before the Oregon Society of Engineers, October 12, 1911.]

I respond with pleasure to the cordial invitation which has been extended to me by this Society through your active secretary, Mr. Stevens, to address you on the general features and possibilities concerning the business and professional opportunities, especially for engineering work, which exist in Chile and other South American countries. It pleases me to note here this evening the marked interest shown by you in learning more about the neighboring twenty Latin-American nations lying south of this great country, which, by their geographical position in the western hemisphere, have been designated by the well-adapted name of Pan-American Union, which is also the title given to that great institution located at Washington, D. C., of which Mr. John Barrett is director general. Mr. Barrett recently visited this city, giving out during the time of his visit in Portland important and instructive facts regarding the commercial development of South America.

At this time I will confine myself to a talk about the possibilities for profitable engineering work in the country I have the honor to represent in view of the progressive material and industrial development now taking place not only in Chile, but in Argentina, Brazil and Peru. These four nations chiefly have been for the last few years the leaders in construction and technical work. They cordially invite the man of intellectual and physical force to coöperate with them. Former generations have been always earnestly interested in their national organization, in finances; but the present generation and the one to come have a genial task in encouraging the technical ability of every man coming to these countries.

The engineering profession is the backbone of the development of resources and wealth of every nation; in fact, there could not be any material progress without the technical knowl-

* Consul of Chile and Ex-Consul of Peru, in Portland, Ore.

edge of the physical forces of nature. An eminent engineer once said that by looking at the railway map of a country he could measure its wealth, its commerce and its industrial possibilities. When undeveloped regions or countries are changing from wilderness to the comforts of civilization, three great factors contribute to their transformation, — population, capital and the energetic force of technical ability and knowledge.

Geographical Position and Territorial Extension of Chile.

The republic of Chile extends over more than thirty-eight degrees of latitude, from 17° 57′ to 55° 59′ south, along the Pacific, stretching from the Samu River to Cape Horn, occupying a long, narrow strip of land between the Andes mountain range and the Pacific Ocean, with a coast line of nearly 3 000 miles and an average width of about 100 miles. The whole country has an area of 291 500 square miles, and a population of 3 449 280. In the central and southern divisions of the country, agriculture, viticulture, apiculture and fishing are carried on to a great extent, while very extensive forests furnish a large variety of fine woods, of a nature too valuable by far for ordinary construction purposes. Mahogany, rosewood, Spanish cedar, ebony and other cabinet woods are among the principal timber products.

Political Organization of Chile.

In this respect we will say that Latin-American countries have been, until recently, very imperfectly known to the average man of North America. Within recent years a large number of books have been written about South America, which, unfortunately, have not been of great use for the purpose of making that part of the western hemisphere known to the world. Some of these books, being inspired by inaccurate and imperfect knowledge of the subject dealt with, do not fill the purpose; others have a limited circulation and frequently contain a great deal of prejudice.

The constitutional charter of the republic of Chile may be said to contain three principal classes of provisions:

(1.) Declarations of a general character, relative to government.

(2.) Declarations relative to the public rights enjoyed by the inhabitants of the country.

(3.) Declarations regarding the constitution, organization and relations of the different branches into which public authority is divided.

Permit me to say a few words upon these three points; I will only give a brief summary.

(1.) The declarations of a general character, as I style them, are those which refer to the form of government, which is popular, representative and centralized; those which make reference to religion, which is to be Roman Catholic Apostolic; those of freedom of thought and faith; those which determine who are Chileans, those so-called being, first, those born within the territory of the republic; second, those born of a Chilean father or mother; third, foreigners who, having resided one year in the country, apply for and obtain a title of citizenship; fourth, those who have a special privilege of naturalization from Congress by virtue of eminent services rendered to the nation.

(2.) The declarations relating to public rights enjoyed by the inhabitants of the country assure to all equality of rights and privileges before the law, since in Chile there exists no privileged class (nor are there any slaves, and once one treads the territory he becomes free); equality of entrance to all positions, employments and functions in the civil service, without restrictions, terms or conditions, except those imposed by law; equitable distribution of taxes, which are in proportion to incomes; the same distribution of every kind of public duties in accordance with the laws, as for instance the military service, which is compulsory in Chile as well as in other countries of Latin America; freedom to stay in any part of the republic, to pass from one part to another, or to leave its territory, if in conformity with the police regulations and without prejudice to another party, it being impossible for any one to be arrested, detained or questioned, except in the form prescribed by law, in respect of which the Constitution lays it down that no one can be condemned unless he is tried fairly under a law in effect prior to the commission of the act upon which judgment is passed and by a court which the law shall have established beforehand.

The declaration of public rights establishes likewise the inviolability of the domicile, the inviolability of epistolary correspondence, the inviolability of all property without distinction as to whether it belongs to private persons or communities, except when for state reasons declared by a law the use or disposal of any such is required (in which case there shall be paid

to the owner such indemnity as shall be agreed upon with him or appraised by the judgment of umpires); likewise the right of holding meetings without prior permission, provided that they be held without weapons and submitted (in squares, streets or other places for the public use) to the police regulations; the right to associate without permission; the right of presenting petitions to the authorities, provided that this be practiced in terms both respectful and proper; freedom for teaching; freedom to publish opinions through the medium of the press; freedom for industries, no kind of labor to be prohibited unless it is opposed to good customs, public security and health, or unless the national interests shall so require and a law so decree; the exclusive right of any author or inventor to his discovery or production for the time that the law shall grant to him, and should the latter require its publication, the inventor shall be given the rightful indemnity.

Finally, the declarations in respect to Chilean public rights determine that free citizens with a right of suffrage, which is only accorded to males, shall have turned the age of twenty-one years, that they can read and write and that their names are inscribed on the electoral registers. The right to the suffrage is suspended for physical or moral inability to act freely and reflectively, being in the condition of a domestic servant or being under judicial proceedings of some defined gravity. The right to the suffrage is forfeited by sentence to the penalties of which mention is made; by fraudulent bankruptcy; by being naturalized in a foreign country; and by accepting appointments, functions or pensions from a foreign government without special permission of the Congress; but in the last case rehabilitation may be obtained through the Senate.

(3.) We come to the last and most interesting part of the Chilean constitutional provisions, that is, those which refer to public authority, the legislative, the executive and the judicial.

The legislative power resides in the national Congress, composed of two houses, one of Deputies and the other of Senators. The Constitution begins by assuring to the members of both chambers inviolability in respect to the opinions they express and the votes they record in the discharge of their functions. They cannot, moreover, without the authorization of the chamber to which they belong, be accused, proceeded against, or arrested in respect to acts of a private character.

The Chamber of Deputies is composed of members elected by the departments into which the country is divided, in the

proportion of one Deputy for each thirty thousand inhabitants, or excess not under fifteen thousand. The Deputies are replaced every three years, but those that have served are eligible for reëlection. In order to be eligible for election as a Deputy, it is only required to hold the right of voting as a citizen.

The Senate is composed of members elected for provinces, comprising several departments. Each province elects one Senator to every three Deputies, and another one if there are two additional Deputies. Half of the Senate is renewable every three years; that is to say, each Senator continues to hold office for a period of six years. To be eligible for the senatorship, it is required that the candidate shall be in full exercise of citizenship, have turned thirty-three years of age and never have been sentenced for transgression of the law punishable by more than three years' imprisonment.

The executive power has for its head the President of the republic, of whom the Constitution says that to him belongs the direction of the state, and he is the supreme chief of the nation. To attain to that office, it is requisite to have been born in Chile, to have the necessary qualifications to become a Deputy and to be at least thirty years of age. He continues in the exercise of his functions for five years, and he cannot be reëlected for the ensuing period, but may be reëlected when another five years shall have expired. His election is made by electors chosen directly for this object to the number of triple that of Deputies. In the event of his being precluded from filling his office, he is replaced by the Minister of the Interior, and in case the latter be not available, then by one of the other members of the ministry in rank of seniority. When a newly elected President is unable to enter upon his duties, he is replaced by the oldest Councillor of State, he not being an ecclesiastic.

Mining Activity.

The most important part of the mineral wealth of Chile, not as regards its present exploitation, but rather as regards its duration for the future, consists in its mines of gold, silver, copper, iron and coal.

With regard to the gold and silver mines, it is well known that these furnished the main source of supplies which the crown of Spain derived from this and the other colonies of America; and it is interesting to note from the statistics that the production of gold and silver in Chile is to-day (as regards silver) one-sixth

part of what it was in the days when Chile was a colony, and (as regards gold) hardly the thirtieth part of what was obtained in the same period. Some people, in the face of these facts, will advance but one explanation, namely, that this is due to the exhaustion of the mines; but the fallacy of this will be apparent to any one who visits Chile. The gold and silver mines of Chile have not been exploited beyond what is called, in technical mining phraseology, the outcrops, and in the majority of instances not even this point has been attained. The total output of gold from Chile since the earliest times when figures and records were kept, for the period of some three hundred and sixty-five years down to the year 1909, was 231 300 000 grams, worth $229 000 000. The production of silver down to the end of 1909 in a total period of two hundred and seventeen years has been 9 000 000 000 grams, worth $319 600 000. But gold and silver mines are not the most important that Chile possesses.

Copper.

Copper has been produced in Chile since the seventeenth century, at first on an insignificant scale, but increasing until it reached its zenith in 1876, from which year down to 1900 Chile held the first place among the copper-producing countries in the whole world. Since then its production has been surpassed by that of several other countries, chiefly the United States and Japan. Chile holds to-day but the eighth position in respect of copper production. To what is this situation due? There is eloquent proof of the reason for the falling off in Chilean copper production. The total amount of copper produced in the world is derived from minerals of a grade lower than 4 per cent., while in Chile that class of mineral is not dealt with. Minerals below a grade of 8 per cent. are unmarketable in the Chilean smelting establishments, unless they consist of a fluxing ore, and even then it is the flux which is valuable, not the copper. It should be mentioned that the special merit and superior demand that Chilean copper has in the general market for the metal is that it contains also gold, silver and other valuable ores, which have only recently received a separate treatment as secondary mineral by-products.

The total output of copper from the year 1601 to the end of 1909, a period of three hundred and nine years, has been 2 200-000 000 kilograms of fine copper, worth $676 600 000, and it must be added that two years ago — that is, since 1908 — the

copper output has attained to more than 40 000 000 kilograms annually, or, in other words, has been doubled in comparison with the output of the years immediately preceding, which may be said to be almost wholly due to the mineral of Collahuasi and of Teniente, which are English and North American companies respectively. They have put up the necessary capital for the construction of the railway branches and the organization of the works in the form demanded by an enterprise of the twentieth century, and not in the way their Spanish predecessors followed in the working of the greater part of the mines of Chile. It is, therefore, no exaggeration to say that copper mining, as well as that of other precious metals, in Chile offers a veritable virgin soil for the investment of foreign capital, with splendid opportunity for mining engineers.

Comparative Outline of Railways.

In my opinion and in the opinion of progressive people, the railways are the backbone of material progress and advancement in civilization, so I will give you a comparative outline of the railways in more important Latin-American countries, Mexico, Argentine, Brazil and Chile.

Mexico. The total extent of the railway system of Mexico is 14 875 miles, the railway of Tehuantepec being worthy of special mention. This crosses the isthmus of that name, and its freight receipts have been so considerable that an extension of the line has been necessitated, and the sum of $3 000 000 had to be spent in habilitating the Port of Salina Cruz, which is its terminus on the Pacific. This means of communication conveys overland the commerce from one ocean to another, and it is generally admitted that, even after the completion of the Panama Canal, its importance will go on increasing.

Brazil. The railways of Brazil now working amount to 11 570 miles, and 2 240 miles in construction, which, after all, is not very great when we take into account the fact that Brazil alone is larger than the whole of Europe, if we exclude Spain and Portugal. By the way, speaking of geographical areas, I would point out that these are not at times properly understood, in a comparative sense, as regards Latin-American countries. It will not, therefore, be beside the point to remark that Uruguay, which is the very smallest of those countries and which by the side of them appears but a mere gem, is very much larger than

England and Wales put together, while the area of Chile is almost equal to that of France and Italy together.

Argentina. The development of railways in Argentina has been considerable. According to the figures contained in a book recently published under the title of "Argentina in the Twentieth Century," the extent of the lines opened to traffic in the year 1887 was 4 000 miles, which represented a capital of approximately $150 000 000; and at the end of the year 1908 the railway system reached a total of 13 250 miles, representing a capital of approximately $850 000 000. According to the same book, in Argentina the value of land in 1908 was estimated at $2 860 000-000; that is to say, the railways trebled their mileage in a space of twenty years, and lands increased in value sevenfold.

Railways of Chile.

In the railway statistics of Latin-American countries, Chile holds the fourth place, — that is to say, she comes after Argentina, Mexico and Brazil in mileage of railways. This may perhaps sound strange to those who know that Chile was the first Latin-American country to have a steam railway. The line from Caldera to Copiapo (fifty miles) inaugurated its service on July 29, 1851; that is, prior to any other American railway excepting those of the United States.

However, those who know the topographical conditions of Chile will find nothing very surprising or abnormal in her being relatively behindhand in comparison with the other three countries referred to. In these countries the construction of railways is comparatively a simple matter. It may be said, especially with regard to Argentina, that it merely consists in laying down the ties and placing rails upon them. In Chile, however, the variable nature of the ground and the many rivers have presented obstacles which can only be overcome by dint of the most arduous labor and enormous investment of capital.

This, in its turn, furnishes an explanation of a circumstance generally known, but not sufficiently understood. Foreign capital has been willingly put into railway enterprises in the Latin-American countries, the great majority of whose railways have been constructed by English companies, to which they still belong; but this has not been the case in Chile. Here the railways, which belong to private companies, comprise 1 898 miles, the greater part of which have been constructed by English

companies with the object of serving their properties in the nitrate region.

The whole of the remaining Chilean railways, which comprise 1 625 miles in actual working, valued at approximately $56 750 000, together with 1 493 miles in construction intrusted to British engineers at a total cost of approximately $35 000 000, and 754 miles under survey, — all these constitute an enterprise wherein the Chileans owe much to the technical knowledge of the British manufacturers of rails, engines and wagons, but very little to the financial assistance of this and other foreign markets, for the reason that it has been carried through by the state of Chile, with Chilean capital, or obtained under the guaranty of the government and refunded by the fruits of national labor and craft. Fortunately, that enterprise, which some have suggested has been too large for the resources of the country, is now, one may say, reaching its goal in its essential part, and Chile is about to be connected from north to south, and will be in communication with the principal ports on her coast by means of a system of 4 892 miles of railway. The most notable circumstances about this fact are the large proportion of the lines at present in construction and shortly to be completed in comparison with the total railway lines in Chile, and their relation to the districts which these lines traverse, being urban or rural properties susceptible of increment in value consequent upon the building of a railway. We have already seen that in the Argentine Republic this increase has been enormous, and in order to imagine what it would be in Chile it must be borne in mind that here the railway traverses regions suited to the raising not only of wheat and cattle, but of every product which can be reckoned as the fruit of skilled cultivation in a soil extraordinarily fertile. In the districts where the railways cross lands unsuited to agricultural developments, the barrenness of the soil is more than compensated for by the presence of a subsoil whose mineral deposits are universally acknowledged to be among the richest in the world.

These circumstances allow one to state with confidence that the completion of the railway system in Chile, in all its essentials, constitutes for the country an economic basis of supreme value; but still there are other circumstances which contribute to prove that the present moment is perhaps the most important in the economic history of Chile. It is only a few years since Chile was joined to Bolivia by a railway which starts from the port of Antofagasta (Chile) and runs to the Bolivian capital, a distance of 1 055 miles, passing over higher mountains than any other

railway in the world. This railway, constructed at the commencement by Chilean capital, but to-day in the hands of an English company, has been the chief artery of the international commerce of Bolivia, which from its inland position is named the Switzerland of South America. This railway was the beginning of a policy of the very greatest importance for the commercial interests of Chile, which is the union of its territory with those of the countries on the other side of the Andes, so as to afford their products an outlet to the Pacific, saving them from the long haul which otherwise they would be confronted with before they reached the Atlantic. It is sufficient to glance at a map of South America to understand how much it meant to Chile to effect the transit of products which, notwithstanding their coming from Bolivia or Argentina, obtain a ready outlet to the Pacific.

The 27th of November, 1909, is a memorable date in the economic history of Argentina and Chile. On that day a British company, with the guaranty from the Argentine and Chilean governments, completed the tunnel through Uspallata, which of all the tunnels pierced is the highest above the level of the sea. Thus was established the railway communication which now renders to the passengers between Chile and the western world an analogous facility to that which other railways crossing the Andes lend to the Argentine trade. The first saves the passengers who come to or from Chile a considerable portion of time in the journey, and the second removes from Argentina a great deal of the expense of freight and transport. With this railway the voyage between Chile and the United States is no longer than one month, not less than three weeks; and it is not much longer to or from Europe. We can say that to-day Chile is practically the same distance from this country as Argentina, with addition of a few days to that from Europe, since a difference of thirty-six hours by train counts but little in a voyage of three weeks, more or less.

Up to the present time, only those capitalists have come to Chile who combine their business pursuits with their taste for traveling and exploration. This perhaps furnishes a reason why the largest part of the foreign capital invested in Chile is British, German, French and Spanish. It is undeniable that the number of British commercial houses scattered all over the globe is due in no small degree to that spirit of travel and sport which is so deeply ingrained in Englishmen. For the future, business in Chile susceptible of development will be quoted in a wider market, and now there will go to Chile not only those capable of

combining business with a certain adventurous spirit in distant countries, but Chile will become a field of investment for the average man of means, that is to say, for all capitalists from this and every other country.

The railways of Antofagasta and Uspallata are not, however, the only international railways of Chile. In August of the present year it is hoped to complete the Chilean section, and in the first month of next year to complete the Bolivian section of the railway from Arica to LaPaz, which is intrusted to English contractors for the sum of £2 750 000, or $13 750 000, and made by the Chilean Government by virtue of a treaty of peace and amity with the Bolivian Government. This railway will have a length of 350 miles and will enable the journey from LaPaz to Arica on the Pacific Coast to be made in twelve hours.

There is also a trans-Andine railway at Antuco which has some thirty-eight miles in course of exploitation and which it is hoped will be concluded at the end of this year. Besides this, there are other concessions for railways which will cross the Andes in regions entirely distinct the one from the other, and with the same purpose of encouraging commercial interchange between Chile and the Argentine, and of affording to the products of the latter a shorter and cheaper route to the Pacific than that which they now have to Atlantic ports. These projected railways are three in number: one from Salta to Mejillones and Antofagasta, another from Tinogasta to Copiapo and Caldera, and a third from Remuco to join with Buenos Ayres Great Southern system, which will admit of traveling from Santiago, the capital of Chile, to Bahia Blanca, the second Argentine port, without changing gage.

Water Power.

In regard to the importance of the waterfalls and their development in Chile, it is sufficient to bear in mind that the whole extent of Chilean territory is a continuously inclined plane, down which the waters of the Cordillera of the Andes Mountains seek their outlet to the sea under conditions which convert them into torrents capable of developing power which in the aggregate would represent many millions of units. There are eighteen large rivers which cross its territory, and the largest number of these streams are navigable rivers, among which the Bueno, the Maule, the Cautin, the Bio-Bio and the Valdivia are the most important, being navigable for distances varying from 25 to 150

miles. The total navigable length of the Chilean rivers is about 975 miles. Thus the work of irrigation is a relatively simple feat of engineering work, for in the majority of cases the only work consists of expanding and branching off the waters of the river beds and availing of the waters that are at present lost or useless. Therefore the work of irrigation in Chile consists in establishing a system of gravitation of the waters and not in pumping them up. This is for irrigation purposes; but for public traffic, means of communication from one point to another, it is necessary to construct substantial bridges and other improvements, which the government is at present encouraging and developing. The government has over 30 bridges of different types under construction, at a total cost of $1 077 510 United States gold, with 35 more under consideration, at a cost of $1 390 103 United States gold.

In this the active engineers find a wide field of opportunity.

The Ports of the Republic.

Chile has a Pacific Ocean coast line of more than 3 000 miles, and every part of the country can be easily reached by water, there being not less than 59 ports in the republic. Fourteen of them are called major ports, which are ports of entry with regular custom houses, and on which the minor ports are dependent. The major ports are Pisagua, Guigue, Tocopilla, Antofagasta, Taltal, Caldera, Carrizal, Bayo, Coquimbo, Valparaiso, Puerto, Mont and Ancud. Punta Arenas in the Straits of Magellan, which is so well known, is a free port, where merchandise, implements, etc., may be imported and exported free of duty.

Chile can be reached from New York by any of the three steamship companies maintaining direct lines: via Buenos Ayres and the Cordillera, via Panama and the West Coast, or via San Francisco, Cal., and the West Coast. The New York and Pacific Steamship Company, the West Coast Line, run steamers between New York and Chilean ports, occupying from forty to fifty-five days, to Valparaiso. By way of Panama the trip is made by the Panama Railway Company's vessels having regular weekly sailings from New York, then crossing the isthmus, and leaving Panama by one of the lines plying on the west coast, it being possible to make the trip by this route in thirty-five days, at a cost of two hundred dollars for first-class passage.

The opening of the Panama Canal, which will take place in a few years, will make it more important to cultivate a better

knowledge of the economic potentialities of the twenty countries lying south of this great country. The completion of that stupendous work will revolutionize the political and commercial relations of the world; will show how near neighbors we are, how close together are the countries of this hemisphere, and what numerous splendid opportunities there are for the fearless man in the practice of his technical profession, as well as for men active in the management of great business affairs. The commercial situation will be greatly altered once the Panama Canal is opened, for this will bring Valparaiso, Callao and Guayaquil, respectively, 3 800, 4 400 and 7 500 miles nearer New York and other North American ports than to Europe via the Magellan Straits.

I will say in conclusion, in having spoken of the resources and possibilities of Chile I have left out of the question the government resources, concerning which it is enough to say that the Chilean Government is beyond doubt the richest in Latin America, when its assets and liabilities are compared with those of other governments there.

I, as a Latin American, heartily appreciate what our North American neighbors have accomplished in business enterprises, as well as in the progressive march and commercial development of Latin America. The United States is the country of the world to which Chile, as well as the other South American nations, I am sure, feel bound by the most cordial ties of true friendship in political and commercial relations.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by February 1, 1912, for publication in a subsequent number of the Journal.]

DISCUSSION OF PAPER, "WATER RESOURCES OF THE STATE OF NEW YORK."

(Volume XLVII, Page 135, October, 1911.)

Prof. H. K. Barrows. — The state of New York has been a leader in the state investigation of water-power resources, and through the State Water Supply Commission it has investigated in a very thorough manner the possibilities of water-power development and of water storage, and the Boston Society of Civil Engineers is fortunate in being able to obtain first hand from the consulting engineer of the New York State Water Supply Commission this interesting paper, which gives the salient features of the more important water-power and storage projects which have been under investigation.

Incidentally, it is important to note that the State Water Supply Commission is procuring accurate data of run-off and precipitation for all streams which are likely to be of importance in the development of the water-power and water-storage facilities of the state. In this way the Commission is laying a sound basis for the planning of the various projects, and it has even in the few years that have elapsed since the beginning of the work, procured a large amount of valuable information regarding run-off and precipitation in New York state.

The isohyetal map of the state of New York referred to by Mr. McCulloh, and published in several of the reports of the Commission, shows in a very striking manner the great variation in precipitation, and therefore in run-off, in the different portions of the state. The interesting fact is also brought out that in general precipitation increases in amount with increase in altitude. This is in accord with the results of investigations made by the speaker upon several rivers in New England which head in the White Mountains, in New Hampshire, and the Green Mountain Range, in Vermont, and western Massachusetts.

It is to be hoped that the work of this Commission can go on for a sufficient length of time to get data of run-off over such a term of years that definite and complete information may be at hand covering the more important streams of the state. The present arrangement as described by Mr. McCulloh, whereby the United States Geological Survey carries on the work under

the general direction of the State Water Supply Commission, seems an admirable one, in that the state secures the services of a trained corps of assistants for this work and at the same time the national government shares the expense.

The speaker has made a somewhat hasty comparison of the storage reservoirs as proposed by the New York State Water Supply Commission with some of the existing storage reservoirs here in New England, and following is this comparison in condensed form.

Outline of Water Storage Projects as Proposed by New York State Water Supply Commission.

River.	Drainage Area. Square Miles.	Annual Precipitation. Inches.	Annual Run-off. Inches.	Storage. Billion Cu. Ft.	Storage. Inches Depth on Drainage Area.	Total Cost.	Cost per Million Cu. Ft.
Sacandaga	1 050	48	26	29	11.9	$4 650 000	$160
Schroon	514	38	23	16	13.3	2 000 000	125
Genesee	948	36	15	18	8.1	4 518 000	250
Raquette	686	45	Probably 25	15	9.4	2 690 000	180

Outline of Storage Reservoirs in New England as Now in Use.

River.	Drainage Area. Square Miles.	Annual Precipitation. Inches.	Annual Run-off. Inches.	Storage. Billion Cubic Feet.	Storage. Inches Depth on Drainage Area.
Kennebec (Moosehead Lake)	1 240	47	24	25	8.8
Penobscot (above Millinocket)	1 880	40±	23	31*	7.1
Androscoggin (above Errol, N. H.)	1 095	36±	23±	30	11.8
Lake Winnepesaukee	360	43	21	8	9.6
Sunapee Lake (N. H.)	46	40±	22	1.5	14.0
Presumpscot River (above Sebago Lake)	436	45	23	13.3	13.1

* It is contemplated to increase storage to about 40 billion cu. ft., or 9.2 in. on 1 880 sq. miles.

In comparing the above tables, it should be kept in mind that the reservoirs in New England consist in nearly all cases of natural lakes which have been raised in water level by the con-

struction of dams at their outlets. No data are available regarding the cost of these reservoirs in New England, but presumably the cost is very much less per million cubic feet of capacity than the figures estimated for the reservoir sites in New York state.

Then, too, in the case of the Sacandaga and Genesee rivers a power development is planned in connection with the dams used for storage, and some portion of the cost as above given can fairly be charged to power development when construction is undertaken.

To ascertain the relative amount of storage development at these different reservoir sites, the speaker has prepared the following table in which the ratio of storage capacity to the average run-off and to the average precipitation at the point in question has been computed.

RATIO OF STORAGE CAPACITY OF RESERVOIRS TO AVERAGE RUN-OFF AND PRECIPITATION.

Storage Reservoir.	Ratio $\frac{\text{Storage Capacity}}{\text{Av. Run-off.}}$	Ratio $\frac{\text{Storage Capacity}}{\text{Av. Precipitation.}}$
Sacandaga	0.46	0.25
Schroon	0.58	0.35
Genesee	0.54	0.23
Raquette	0.37	0.21
Kennebec	0.37	0.19
Penobscot	0.31	0.18
	(0.40)	(0.23) (as contemplated)
Androscoggin	0.51	0.33
Lake Winnepesaukee	0.46	0.22
Lake Sunapee	0.63	0.35
Presumpscot	0.57	0.29

The reservoir sites on the Sacandaga, Schroon and Genesee rivers may be said to represent fairly well the extent to which storage is usually practicable on large rivers under favorable conditions, here in the East, and it will be noted that these three reservoir sites are developed to a capacity of about 0.55 of the average yearly run-off, or about 0.28 of the amount of the average yearly precipitation. Even with this amount of storage development, there will be more or less waste of water in the wetter years.

It is likely that the rivers such as the Kennebec, Penobscot and Androscoggin will be still further developed in respect to storage capacity. Of course the presence or absence of good reservoir sites has much to do with the extent of storage development. On the smaller drainage areas, of which Lake Winnepesaukee, Lake Sunapee and the Presumpscot River are good

examples, even higher degrees of storage development are warranted, if in such situations storage capacity can be obtained at low expense, and in some cases it is entirely practicable to develop a storage capacity sufficient to hold the entire average yearly run-off.

In closing, the speaker wishes to say a word of commendation of the high character of the engineering and scientific work that has been carried on by the State Water Supply Commission of New York under the direction of Mr. McCulloh. The reports of this Commission are among the most valuable relating to hydrology, and the investigation of water resources of any that have been issued either by the national government or by the states, and the data given therein are of great general value, in addition to providing a sound basis for legislation and action toward the development of the water resources of the state.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XLVII. JULY, 1911. NO. I.

PROCEEDINGS.

Boston Society of Civil Engineers.

STERLING, MASS., JUNE 21, 1911. — A regular meeting of the Boston Society of Civil Engineers was held at the Sterling Inn, Sterling, Mass., at the close of the dinner served in connection with the excursion to the various works of the Metropolitan Water Works, and was called to order by the President, Charles T. Main, at 3.15 o'clock P.M. Thirty-five members and visitors present.

It was voted to dispense with the reading of the record of the last meeting and to approve the same as printed in the June *Bulletin*.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members — Messrs. Burtis S. Brown, Henry W. Durham and Edward C. Sherman.

Associates — Messrs. Thomas H. Keenan and John M. Keyes.

Junior — Mr. George W. Lewis.

No further business coming before the Society, on motion duly made and seconded, at 3.19 o'clock it was voted to adjourn.

S. E. TINKHAM, *Secretary*.

Association of Engineering Societies.

Vol. XLVII. SEPTEMBER, 1911. No. 3.

PROCEEDINGS.

Montana Society of Engineers.

Butte, Mont., May 13, 1911. — The meeting for the current month was held at the appointed place and time, Vice-President Robt. A. McArthur in the chair. The Secretary read the minutes of the previous meeting and no corrections were made. Jonathan Sewell and Howard E. Brillhart were elected to active membership in the Society. Mr. Packard called the attention of the members present to the inconsistencies along the line of the location of mining claims. Messrs. McArthur, McMahon and Simons discussed the subject at issue, and the matter was deferred until the September meeting. The Society then adjourned to meet the second Saturday of September.

Clinton H. Moore, *Secretary.*

Association of Engineering Societies.

Vol. XLVII. OCTOBER, 1911. No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, May 17, 1911.—The 705th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, on Wednesday, May 17, 1911, at 8.15 P.M., Vice-President Hunter presiding. There were present 28 members and 9 guests.

The minutes of the 704th meeting were read and approved.

Mr. J. D. Robertson was elected to membership.

The report of the Joint Council was read, recommending that the St. Louis Section of the American Society of Engineering Contractors be affiliated with the Club on the same basis as the other national societies.

Mr. Schuyler moved that the American Society of Engineering Contractors, St. Louis Section, be accepted by the Club for affiliation. Motion duly seconded and unanimously carried.

A letter from the American Institute of Electrical Engineers, St. Louis Section, asking the Club to pass certain resolutions favoring the establishment by Congress of a permanent commission of supervision of patents, was read. On motion of Mr. Wall, the matter was referred to the Executive Committee to report back to the Club.

Mr. C. L. Hawkins, engineer of the Track Department of the United Railways, presented an illustrated paper on the "Sand Drying Plant of the United Railways Company." Mr. Hawkins described the construction and operation of the plant, giving cost items for each.

Adjourned, 9.45 P.M.

W. W. Horner, *Secretary*.

Boston Society of Civil Engineers.

Boston, September 20, 1911.— A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M., President Charles T. Main in the chair. Seventy-eight members and visitors present.

It was voted to dispense with the reading of the record of the June meeting and to approve the same as printed in the September *Bulletin*.

The Secretary reported for the Board of Government that it had elected Mr. Byron Adams Robinson a member of the Society.

The Secretary also reported that the Board of Government had appointed the following committee to recommend the award of the Desmond FitzGerald Medal for the best paper published by the Society during the year ending with the month of September, 1911, Messrs. Desmond FitzGerald, Harold K. Barrows and Chester J. Hogue.

The Secretary announced the death of Mr. George C. Dunne, an associate of the Society, whose death occurred on May 23, 1911, and by vote the President was requested to appoint a committee to prepare a memoir. The President appointed as that committee, Mr. Frank A. Barbour.

On motion of Mr. Gow, the thanks of the Society were voted to Lieut.-Col. C. B. Wheeler, commanding officer at the Watertown Arsenal; to Captain Shinkel and to Mr. H. D. Whittemore, for courtesies extended to members of the Society during the excursion this afternoon.

Mr. T. Howard Barnes read a short paper on "Pile Protection" which was illustrated by lantern slides.

Mr. J. W. Rollins described the condition of the foundation under one of the piers of the bridge at Fall River where the *teredo* had eaten the piles and grillage so badly that the pier had sunk and rendered the bridge unsafe. Mr. F. W. Hodgdon spoke of the work of the *teredo* and the *limnoria* in Boston Harbor and showed specimens of their work.

Mr. Barnes then gave an informal talk on "Guatemala and Her People from a Wayfarer's Point of View," which he illustrated with a large number of lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., October 9, 1911. — The 6th regular meeting of the year was called to order at 8.30 o'clock P.M. in the Society's quarters in the Old State Capitol Building, by President L. P. Wolff. There were present 12 members.

The minutes of the previous meeting were read and approved.

The resignation of Mr. H. Fernstrom was read and accepted, to be effective December 31, 1911.

A communication was read from the Organizing Committee of the Sixth Congress of the International Association for Testing Materials, inviting this Society to send a representative to the Sixth Congress of that Association, to be held in the Engineering Society's Building, 29 West Thirty-Ninth Street, New York City, beginning September 3, 1912. On motion carried, the Secretary was directed to advise said Congress that this Society would be very glad to send a delegate, as requested.

Mr. J. D. DuShane invited the members of the Society to come to Hastings, Minn., and inspect the workings of the new hydraulic dredge, which invitation was accepted with thanks by the Society. A committee

consisting of Messrs. Wolff and Armstrong were delegated to provide automobiles, and the Secretary was directed to advise all members with reference to the invitation and requesting all who found it possible to attend to meet at the Old Capitol at 10 A.M. Friday, October 13, 1911. Luncheon and refreshments will be provided on the boat at Hastings.

Meeting adjourned by mutual consent at 9.40 P.M.

D. F. JURGENSEN, *Secretary*.

Association of Engineering Societies.

Vol. XLVII. NOVEMBER, 1911. No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, September 20, 1911. — The 706th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday, September 20, at 8.15 P.M., President Von Maur presiding.

The meeting was a special Ladies' Night. The total attendance was 110, of whom about 38 were ladies.

The Secretary read a letter from Mr. Otto Karbe, chairman of the Free Bridge Committee, requesting that the Club appoint a special committee to investigate the relative merits of the approach as proposed and that advocated by Mr. F. G. Gerhart, or to recommend as they see fit. Mr. Dodds moved that the President appoint a committee to report on the matter either to the Club or to the general committee. Motion seconded and carried. The President subsequently appointed the following committee: Dr. C. M. Woodward, chairman; Mr. M. L. Holman, Mr. E. J. Spencer, Mr. B. L. Brown, Mr. O. W. Childs.

Mr. Hiram Phillips presented a paper on "The Colorado Springs Waterworks," which was illustrated with a large number of colored lantern slides.

After the paper the meeting adjourned to the reading-room, where elaborate refreshments were provided.

Adjourned at 11 P.M.

W. W. Horner, *Secretary.*

St. Louis, October 4, 1911. — The 707th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday, October 4, 1911, at 8.15 P.M., President Von Maur presiding. There were present 62 members and visitors.

The minutes of the 706th meeting of the Club were read and approved, and the minutes of the 496th, 497th, 498th, 499th and 500th meetings of the Executive Committee were read.

The Treasurer gave the following report:

ENGINEERS' CLUB STATEMENT, OCTOBER 1, 1911.

General Fund	$1 914.25		
Fund	307.16		
Library Fund.			$40.96
	$2 221.41		40.96
Balance	$2 180.45		
Accounts:			
Bank Commerce		$39.42	
Mercantile Trust Company		1 428.86	
St. Louis Union Trust Company		712.17	
		$2 180.45	
Delinquent dues, October 1, 1911		$550.00	
Collections, 1911		$3 066.80	

W. E. ROLFE, *Treasurer.*

The following gentlemen were elected to membership:

For membership — J. E. Allison, F. A. Berger, Ludwig Gutman, J. B. Dean, C. H. Miller.

For associate membership — Robert Sieger, R. D. E. Claxton.

The application for membership of E. H. Abadie was read.

Mr. A. S. Langsdorf moved that the President be authorized to appoint a committee to consider the patent laws. Motion seconded and carried.

Mr. C. W. Martin, engineer of the Bridge Division of the Street Department, presented the paper of the evening, on "Methods of Reinforced Concrete Design."

Adjourned.

W. W. HORNER, *Secretary.*

ST. LOUIS, OCTOBER 18, 1911. — The 708th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, October 18, 1911, at 8.30.

This meeting was a joint meeting with the St. Louis Section of the A. I. E. E. Mr. G. W. Lamke, chairman of the local section A. I. E. E., presided. The total attendance was 39, of whom 12 were members of the Club, 10 of the A. I. E. E., 6 of both, and 11 were guests.

The following-named gentlemen were proposed for membership in the Club:

As members — S. K. Smith, C. A. Hobein, Jr., F. J. Bullivant, C. S. Goldsmith, Thos. Knobel, R. B. Brooks, J. C. Higdon.

As junior — J. A. Stifelman.

All other business was suspended.

Mr. J. L. Carlisle, of the Maloney Electric Company, presented a paper on "A Comparison of Types of Transformers." The paper was illustrated with lantern slides, and several transformers, one in various stages of construction, were shown.

Adjourned 10.15 P.M.

W. W. HORNER, *Secretary.*

Association of Engineering Societies.

Vol. XLVII. DECEMBER, 1911. No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, November 1, 1911. — The 709th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, on Wednesday, November 1, 1911, at 8.15 P.M., President Von Maur presiding. There were present 34 members and 12 visitors.

The minutes of the 707th and 708th meetings were read and approved, and the minutes of the 501st and 502d meetings of the Executive Committee were read.

The following gentlemen were elected to membership:

Members — R. B. Brooks, C. S. Goldsmith, J. C. Higdon, F. J. Bullivant, C. A. Hobein, Jr., E. H. Abadie, S. K. Smith.

Junior Member — J. A. Stiffelman.

The names of the following were proposed for membership:

F. R. Mott, C. H. Quackenbush, G. S. Bergendahl, C. S. Ruffner, N. A. Melick.

It was moved by Mr. Woermann, seconded and carried, that the Club approve the action of the Executive Committee in accepting and forwarding the report of the Committee appointed to investigate the East Side Approaches to the Municipal Bridge.

The following committee was elected to nominate officers for 1912:

E. L. Ohle, chairman; L. C. F. Metzger, W. C. Zelle, F. T. Adler, John Hunter.

Mr. Langsdorf moved that the date of the annual banquet be set for December 15, and that the price per plate should not exceed three dollars, as recommended by the Executive Committee. Motion seconded and carried.

Mr. A. C. Janni, engineer in the Bridge Division of the Street Department, presented a paper on "The Kingshighway Viaduct." This paper contained a description of both design and construction methods, and was illustrated with lantern slides.

Adjourned.

W. W. Horner, *Secretary*.

St. Louis, November 15, 1911. — The 710th meeting of the Engineers' Club was held at the Club rooms, 3817 Olive Street, on Wednesday, November 15, 1911, at 8.15 P.M., President Von Maur presiding. There were present 40 members and 21 visitors.

The minutes of the 709th meeting of the Club were read and approved, and the minutes of the 503d meeting of the Executive Committee were read.

The following gentlemen were elected to membership: C. S. Ruffner, N. A. Melick, C. H. Quackenbush, C. S. Bergendahl.

The following gentlemen were proposed for membership: C. L. Holman, Wm. S. Merkle, O. F. Huch, R. T. Toensfeldt, F. N. Jewett, Wm. F. Gradolph, J. W. Himmelsbach, C. L. Orth, Edw. Gray, J. H. Boughton, A. B. Johnson, C. H. Specht, Anthony Neumayer.

The Nominating Committee presented the following report:

To the Members of the Engineers' Club of St. Louis: *Gentlemen,* — As your Nominating Committee, we beg leave to nominate the following members of the Engineers' Club of St. Louis, to fill the respective offices for the ensuing year:

For President — A. S. Langsdorf.
For First Vice-President — John Hunter.
For Second Vice-President — H. H. Humphrey.
For Secretary — W. W. Horner.
For Treasurer — W. E. Rolfe.
For Librarian — E. O. Sweetser.
For Directors — E. L. Ohle and Hans Toensfeldt.
For members of the Board of Managers of the Engineering Societies — W. S. Henry, Baxter Brown, H. A. Wheeler.

Respectfully submitted,

(Signed) E. L. Ohle, *Chairman.*
L. C. F. Metzger.
John Hunter.
Wm. C. Zelle.
F. T. Adlen.

Mr. F. N. Speller, chief metallurgical engineer of the National Tube Company, presented a short paper, followed by a talk illustrated with a remarkable collection of slides, on " The Development of the Modern Tube Industry." The paper gave rise to considerable discussion, in which Messrs. Von Maur, Mitchell, Woermann, Hunter and McArthur participated. Mr. Fish moved a vote of thanks to Mr. Speller, which was carried unanimously.

Adjourned.

W. W. Horner, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., October 18, 1911. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M., President Charles T. Main in the chair.

The members of the American Society of Mechanical Engineers and of the Boston Section of the American Institute of Electrical Engineers joined in this meeting, the attendance being 180.

It was voted to dispense with the reading of the record of the September meeting and to approve the same as printed in the October *Bulletin.*

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members — Messrs. Cornelius Beard and Frank F. Jonsberg.

Juniors — Messrs. Charles A. Campbell and George E. Chamberlin.

The Secretary also presented for the Board the following vote: *Voted*, "That the Board of Government recommend to the Society at its meeting of this evening, that a committee of three from the Society be appointed by the President to consider the report of the Committee on Fire Prevention of the Boston Chamber of Commerce and to report in print with the notice of the November meeting of the Society recommending action on the suggested endorsement of that report for discussion at that meeting as provided by the Constitution, and that November 15, 1911, is thereby designated by the Board as the date for such discussion."

The report was accepted and the recommendation adopted.

The President has appointed as this committee, Messrs. Henry F. Bryant, Frank A. McInnes and Harrison P. Eddy.

The Secretary announced the death of Edward W. Hadcock, a member of the Society, which occurred on October 10, 1911, and by vote the President was requested to appoint a committee to prepare a memoir. The President appointed as that committee Mr. Frank W. Hodgdon.

The President then introduced Mr. Charles Robinson, who read the paper of the evening which had been prepared by Mr. Fred A. Wallace, engineer of the Pacific Mills of Lawrence, entitled " Power System of the Pacific Mills, Methods and Rules for, and Cost of Operation." The paper was fully illustrated by lantern slides.

In the discussion which followed the reading of the paper, members of the American Institute of Electrical Engineers and of the American Society of Mechanical Engineers took a prominent part.

After passing a vote of thanks to Mr. Wallace, the author of the paper, and to Mr. Robinson who read the paper, the Society adjourned.

S. E. Tinkham, *Secretary*.

Boston, Mass., November 15, 1911. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m., President Charles T. Main in the chair; 154 members and visitors present.

It was voted to dispense with the reading of the record of the October meeting and to approve the same as printed in the November *Bulletin*.

The Secretary reported for the Board of Government that it had elected the following to membership in the grade of member: Messrs. Walter H. Bacon, Henry A. Herrick, Arthur Howland, William F. Uhl and Mason T. Whiting.

The President stated that the business before the meeting was to act upon a report of the committee appointed at the last meeting to recommend action on the suggested endorsement of the report of the Committee on Fire Prevention of the Boston Chamber of Commerce. The report was printed with the notice of this meeting.

Mr. Bryant moved the adoption of the vote submitted in the report, namely, That the Boston Society of Civil Engineers hereby endorse the general recommendations printed on pages 7 and 8 of the report of the Com-

mittee on Fire Prevention of the Boston Chamber of Commerce under date of September, 1911.

The vote was adopted, only one member voting in the negative.

The President announced that under the Constitution of the Society the vote must now be submitted to a letter ballot.

The meeting was then turned over to the American Society of Mechanical Engineers, Prof. E. F. Miller in the chair, who introduced Prof. Charles L. Norton, of the Massachusetts Institute of Technology. Professor Norton read an exceedingly interesting paper entitled, "Some Refractory Substitutes for Wood." The paper was illustrated by lantern slides and was discussed by members of both the Mechanical and Electrical Engineers' societies as well as by members of this Society.

S. E. Tinkham, *Secretary.*

Sanitary Section.

The regular December meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at the Boston City Club, December 6, 1911, at 7.30 o'clock P.M., with Mr. George A. Carpenter in the chair. The meeting was preceded by the usual dinner at 6 P.M. There were 34 members and guests present at the dinner, and about 43 at the discussion.

Messrs. George C. Whipple, J. A. Lockhart and Clarence W. Rolfe were enrolled as members of the Sanitary Section.

Mr. L. K. Rourke. Commissioner of Public Works, City of Boston, gave an interesting talk with special reference to the sanitary work in the Canal Zone at Panama. Mr. Rourke's talk was illustrated with lantern slides descriptive of both the sanitation and general work at Panama.

This was followed by a paper on the "Sanitation of Construction Camps along the Catskill Aqueduct" by Mr. A. J. Provost, Jr., of the firm of Lederle & Provost, of New York City, which was also illustrated with slides.

Mr. W. W. Locke, sanitary inspector of the Metropolitan Water Works, read a short paper on the "Sanitation of the Contractors' Camps in the Wachusett Basin" and on the inspection carried on in the watersheds of the Metropolitan Water Supply.

Additional facts were given by Mr. Hiram A. Miller, and Mr. Edmund M. Blake and others entered into the discussion.

A vote of thanks was extended to Messrs. Rourke, Provost and Locke, and the meeting adjourned at 9.45 P.M.

Edward Wright, Jr., *Clerk pro tem.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., November 13, 1911. — The seventh regular meeting of the year was called to order at 8.30 P.M. in the Society's quarters in the Old State Capitol Building, by President L. P. Wolff. There were present 20 members and 7 visitors.

The minutes of the previous meeting were read and approved.

It was regularly moved and carried that a vote of thanks be extended to Mr. J. D. DuShane, and the Entertainment Committee. for the enjoyable

and educational trip which was taken to Hastings, Minn., on October 13, 1911, to inspect the hydraulic dredge in operation at that point.

A communication was read from the American Road Builders Association, inviting the Society to send a representation to the eighth annual convention of the American Road Builders Association, to be held at Rochester, N. Y., on November 14–17, 1911. On account of the letter not reaching the Secretary in sufficient time to notify the Society, no action could be taken, and the Secretary was directed to acknowledge and thank the Association for the invitation.

The petition of L. G. Couter, junior member, for advancement to full membership was read and granted. Applications of Parker Simons, W. E. King, J. C. Utton and Donald B. Fegles, for full membership into the Society, were read. On motion carried, the Secretary was directed to cast the ballot electing the applicants as petitioned. They were declared elected.

A general discussion, lead by Mr. J. H. Armstrong, was then participated in, on "Municipal Pavements and Macadams," which engaged the meeting until 10 o'clock P.M., when adjournment was taken by mutual consent.

D. F. JURGENSEN, *Secretary.*

ST. PAUL, MINN., DECEMBER 11, 1911. — The eighth and last regular meeting of the year was called to order at 8.30 P.M., in the society's quarters in the Old State Capitol building, by Vice-President J. H. Armstrong. There were seven members present.

The minutes of the previous meeting were read and approved.

The program of the convention of the American Society of Mechanical Engineers, held in New York City during the week of December 4, 1911, was read and ordered filed. The Secretary was directed to acknowledge receipt and thank such society for the same.

The applications of William G. Hoyt and Stephen B. Soule for full membership into the society were read, and, on motion, carried. The Secretary was directed to cast a ballot of the Society and elect the applicants as petitioned. They were declared elected.

It was decided that the Society would have the customary banquet at the conclusion of business at the twenty-ninth annual meeting of the Society, which will be held January 8, 1912. Messrs. Oscar Claussen, James D. DuShane and Oscar Palmer were appointed as the committee to make all arrangements for the banquet, and are to report such arrangement to the governing board of the Society as soon as possible, for authorization. The Secretary was directed to extend invitations to the banquet to the Hon. H. P. Keller, Mayor of St. Paul; Andrew Rinker, City Engineer, Minneapolis, Minn.; to the Governing Board of the Engineers' Club of Minneapolis, Dean Francis C. Shenehon, of the College of Engineering, University of Minnesota, Minneapolis, Minn.; Mr. George W. Cooley, Secretary State Highway Commission; Major Francis R. Shunk, Corps of Engineers, U. S. A., and Hon. A. O. Eberhart, Governor of Minnesota.

There being no further business, the meeting adjourned.

D. F. JURGENSEN, *Secretary.*